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"Studies and Surveys In The Field Of Printed Circuit Boards and Foil Clad Laminates"

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LITTON INDUSTRIES
U. S. ENGINEERING CO. DIVISION

STUDIES AND SURVEYS IN THE FIELD OF PRINTED CIRCUIT BOARDS AND FOIL CLAD LAMINATES

FINAL REPORT,

1 JULY 1960 TO 30 JUNE 1961

LITTON INDUSTRIES

U.S. ENGINEERING CO DIVISION

VAN NUYS, CALIFORNIA

PREPARED FOR

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FORT MONMOUTH PROCUREMENT OFFICE

PROCUREMENT MANAGEMENT DIVISION B

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ABSTRACT

This report has been ~~prepared to present the complete~~ results of a study covering ~~five~~ areas of interest in the evaluation of foil clad laminates used for the manufacture of printed wiring boards. This study, ~~conducted by the U. S. Engineering Co. Division of Litton Industries under contract number DA36-039-[illegible]~~ covers the design and construction of necessary testing equipment, the establishment of testing procedures, and the gathering of experimental data to provide more complete information for specification requirements for these materials.

This report is divided into five areas of discussion as follows: Allowable limits per square for nicks, pin holes and scratches on printed wiring boards; Study of insulation resistance on foil clad laminates; Peel strength after dip solder; Peel strength at elevated temperatures; and a complete evaluation of copper clad paper base epoxy laminates. Specimen preparation, testing methods, an analysis of experimental data, and where appropriate, recommended specification provisions are presented under each task.

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1. Introduction

1.1 Purpose - This report has been prepared to present the results of a study of some of the physical, mechanical and electrical properties of foil clad laminates for printed wiring boards, and where appropriate, to submit recommendations for specification revisions, based on the data taken.

1.2 Background - The successful utilization of printed circuitry in electronic systems, particularly for military applications, demands careful evaluation, not only of the completed boards, but of the base material from which they are manufactured. In order to conform with the Department of Defense Standardization Program, acceptance standards for both the basic copper clad laminates and the printed circuit boards made therefrom must be established on an industry wide basis. These standards must fulfill a two-fold purpose: (1) to ensure that acceptable material is being used to produce acceptable boards, and (2) that the standards so established must allow the industry to produce these boards without the risk of excessive scrappage because of too many restrictions.

Evaluation of foil clad laminates and printed wiring boards requires examination of physical, electrical and mechanical properties. In some of these areas, both criteria for allowable limits and acceptable testing techniques exist. In other areas they may not exist or may be subject to question by the consumer or the industry. The problem, then is two-fold; (1) complete criteria for allowable limits must be established, and (2) testing method must be developed or evaluated from the standpoint of practicability and reproducibility over a wide range of different types of material produced by many different manufacturers.

Because of the widespread interest in the use of paper base epoxy in the printed circuit field in the last few years, it has become necessary to evaluate this material with respect to physical, electrical, and mechanical properties in order to establish property values for the various parameters measured in MIL-P-13949B.

1.3 Scope - The scope of this study has been broken down into five tasks. Task A is concerned with establishing criteria for allowable limits per square, for pin holes, nicks and scratches on printed wiring boards. The work accomplished and reported under this task is concerned with fabrication of test specimens, completion and testing of the circuit design for measuring temperature rise in a copper conductor, testing of the specimens and evaluation of the effect of the temperature increase by making peel strength measurements on specimens already tested. Task B is concerned with the evaluation of "bullseye" and "comb patterns" presently used by the military and commercial organizations for measuring insulation resistance of copper clad laminates, and to establish a method of measuring insulation resistance which is practicable and reproducible when tested in a humidity chamber at specified conditions. (10 cycles of method 106-MIL-STD-202A). The work accomplished under this task includes the modification of the insulation resistance test design, special cleaning procedures for the bullseye and comb pattern test specimens, and analysis of the experimental data. Task C is concerned with the collecting of peel strength data on copper clad laminate test specimens after dip solder, and to evaluate the reproduceability of these results by comparing them with values obtained when controlled amounts of solder are used. Task D is concerned with performing peel strength tests at elevated temperatures in accordance with the test method in MIL-P-13949B. The work accomplished under this task involves specimen preparation and design and construction of a peel strength chamber. Task E is concerned with the complete evaluation of paper base epoxy laminates in accordance with the requirements of MIL-P-13949B, so that this material can be included in the next revision of the specification.

1.4 References - The following documents have been used to start the work reported on. Specifications and standards marked with an asterisk (*) are considered of particular interest to the tasks.

MILITARY SPECIFICATIONS

*MIL-P-13949B	Plastic Sheet, Laminated, Copper Clad (for Printed Wiring)
MIL-P-22324 (Ships)	Plastic Sheet, Laminated, Thermosetting, Paper Base, Epoxy Resin
*MIL-P-55110	Printed Wiring Boards
*MIL-R-978 (Ships)	Reports and Microfilm: Research and Development (for Electronic Equipment)

MILITARY STANDARDS

*MIL-STD-202A	Test Methods for Electronic and Electric Component Parts; Method 106A, Moisture Resistance; Method 302, Insulation Resistance
*MIL-STD-275A	Printed Wiring for Electronic Equipment

FEDERAL SPECIFICATIONS

*L-P-406B	Plastics, Organic: General Specifications, Test Methods

Method 7031 Water Absorption Test

Method 2021 Flammability of Plastics over 0.050 Inch in Thickness

*American Society for Testing Materials

Designation D570-54T	Water Absorption of Plastics
Designation B193-49	Method of Test for Resistivity of Electrical Conductor Materials

Miscellaneous Publications

*SCL-6225	Design Requirements for Auto-assembled Army Signal Electronic Equipment
*SCL-2101K	Signal Corps Technical Requirement; Technical Reports

Books and Pamphlets

"Instruction Manual, Model 610A, Multi-Purpose Electrometer and Accessories", Keithley Instruments, Inc.

"Instruction Manual, Sargent-Slomin Analyzers, Catalog Nos. 29459-65", E. H. Sargent & Co.

"Do's and Don'ts for Fabricating Laminates", General Electric Company.

"Manual Instructions, Dillon Test Machine", Model M-Serial 577 by W. C. Dillon and Company.

"Operating Instructions, for Type 544-B Megohm Bridge", General Radio Company.

"Directions for Kelvin Bridge Ohmeter No. 4285", Leeds & Northrup Company.

"Instruction and Operating Manual for Vacuum Tube Voltmeter, Model 412A", Hewlett-Packard Company.

"Instructions for The Operation of, Missimers Model M3.3 Modular Test Chamber, Missimers Incorporated.

Progress Reports

"Characterization of Metal-Insulator Laminates", by D. S. Hoynes, April 1953 through April 1954, National Bureau of Standards Report No. 3392.

"Characterization of Metal-Insulator Laminates", by D. S. Hoynes, January 1955 through December 1955, National Bureau of Standards Report No. 4283.

"Specification Development Report on Elevated Temperature Bond Strength of Copper Foil Clad Plastic Laminates for Printed Circuitry", Lab. Project 5315-161 Final Report, 12 December 1958, Bureau of Ships.

"Specification Development Report on Elevated Temperature Bond Strength of Copper Foil Clad Plastic Laminates for Printed Circuitry", Lab. Project 5315-161, Progress Report 1, Bureau of Ships Problem No. ST-161, 14 August 1958.

"Evaluation Report of Electrical Resistance of Foil Clad Phenolic and Epoxy Laminates", Lab. Project 4960-C-61.5-100, Final Report, Problem No. 1101-C-61.5-100 Allotment 600008/56, Bureau of Ships, 28 December 1956.

"Insulation Research Program", Progress Report, June 1 to September 1, 1959, University of Delaware.

"Insulation Research Program", Progress Report, September 1, to December 31, 1959, University of Delaware.

"Insulation Research Program", Progress Report, January 1, to April 25, 1960, University of Delaware.

"Insulation Resistance Program", Summary of Investigations and Results, Joint ASTM-EIA-NEMA Project, May 20, 1060, University of Delaware.

"Minutes of Joint Steering Committee on Insulation Research", May 25, 1960, University of Delaware, Newark, Delaware.

"Resistivity - Its Meaning and Significance", by Milton G. Young, Symposium Paper, Sponsored by the American Society of Testing Materials, ASTM Meeting at Detroit, Michigan, October 6, 1960.

"Use of Low Cost Foil-Clad Paper Base Epoxy Laminates for Printed Wiring Boards", H. L. Uglione, Jr. Insulation, September 1960.

Progress Reports and Communications

Contract No. DA36-039 SC85383, Letter to Commanding Officer U. S. Army Signal Equipment Support Agency, Fort Monmouth, New Jersey, Attention: Mr. A. Z. Orlowski, from U. S. Engineering Co. Division Litton Industries, July 27, 1960.

First Quarterly Progress Report, "Studies and Surveys in the Field of Printed Circuit Boards and Foil Clad Laminates" 1 July 1960 to 30 September 1960. Contract No. DA 36-039 SC85383.

Second Quarterly Progress Report, "Studies and Surveys in the Field of Printed Circuits and Foil Clad Laminates 1 October to 31 December 1960. Contract No. DA36-039 SC85383.

Third Quarterly Progress Report, "Studies and Surveys in the Field of Printed Circuit Boards and Foil Clad Laminates" 1 January to 31 March 1961. Contract No. DA36-039 SC85383.

1.5 Conferences - A meeting was held on July 5 and 6, 1960 between representatives of the U. S. Engineering Co. and USASESA to discuss the tasks assigned under the contract. As a result of this meeting, it was decided that work on Task E, the evaluation of paper epoxy should be started immediately, rather than left until last as had been originally planned. On July 8, a meeting was held between representatives of U. S. Engineering Co. and Mr. D. S. Hoynes of the Bureau of Standards. This discussion covered previous work done in measuring and evaluating current carrying capacities of varying widths of printed circuit conductor lines. Copies of the reports covering this work were obtained. On July 11, a meeting was held at the University of Delaware with Professor M. A. Young, concerning a research program being conducted under a joint industry sponsorship on insulation resistance of copper clad material. Although their measurements were being taken at a constant temperature and humidity, as opposed to the variable conditions required by Method 106 of MIL-STD-202, considerable valuable information was received on techniques of measurement on parts under humidity chamber conditions. On September 8 and 9, a meeting was held at U. S. Engineering Co. with Miss Sarah Rosen of USASESA. This meeting covered discussions of the progress made, and plans for balance of the work on all the tasks, with particular emphasis on the evaluation of copper clad paper base epoxy. On October 10 through 12, a meeting was held at U. S. Engineering Co. with Mr. A. Z. Orlowski of USASESA. General discussions were held concerning the progress of the program. At this meeting, following an inspection by the USASESA representative, permission was granted to allow the Delsen Co., a local Engineering Testing Company to subcontract the dielectric testing necessary for the completion of Task E, the evaluation of paper epoxy.

On October 23 through 27 visits were made to the following companies to determine if any work was being done which might be of value or be worth including in this program:

Martin Company - Denver, Colorado. Talked to Mr. Frank Lane and Mr. Lew Charles. They stated that the only work which had been done which might be of value was some earlier work on current carrying capacity of conductor lines, but the report was not immediately available.

Sperry Utah Engineering Laboratories - Salt Lake City, Utah. Talked to Mr. T. A. Roberts, Standards Engineer. No work being done which would be of value.

Boeing Airplane Company - Seattle, Washington. Visited Mr. J. D. Rough, Mr. Bob Cockrell. Boeing has done a considerable amount of work on material evaluation, but unfortunately, it does not fall into the present requirements of MIL-P-13949B, and therefore would be of little use.

From December 4 through 16, a series of visits were made to other companies and military installations, as well as USASESA. These are outlined below:

Dec. 7 - A repeat visit was made to Professor Young at the University of Delaware to review measurement techniques of Insulation resistance in the humidity chamber, and pick up any additional data which may have been accumulated since the last visit.

Dec. 11 and 12 - A meeting was held with USASESA representatives during this period to discuss progress of the various tasks, and particularly the final data on the evaluation of copper clad paper epoxy. Some suggestions for tabulating the data were made and final specification values were discussed.

Dec. 13 - Visited Wright Air Development Depot at Dayton. No Material evaluation work which would be suitable for this study is being done there.

Dec. 14 - Indianapolis, Naval Avionics Facility, Mr. Donald Martz. Considerable active printed wiring board research going on at this facility, but no data was available which would fall within the scope of this study.

From March 21 through March 30, the following visits were made:

Sperry Company, Great Neck, N. Y.

General Electric LMD, Syracuse, N. Y.

Chrysler Missile Division

Burroughs Company, Detroit, Michigan

Collins Radio Company, Cedar Rapids, Ia.

On June 8 and 9 a meeting was held at the U. S. Engineering Co. with Mr. A. Z. Orlowski of USASESA. The third quarterly progress report was reviewed, and final plans were made for completing the program.

2. Task A - Allowable Limits Per Square of Nicks, Pin Holes and Scratches on Printed Wiring Board.

2.1 Approach

To measure and evaluate the effect of cross-sectional area reduction on the current carrying capacity of a specified length of conductor, a series of artworks were designed to produce printed wiring boards with conductor lines of different widths, having increasing degrees of area reduction represented by notches of measured depth. By plotting the increase in temperature of the conductor at the point of reduction against the current through the conductor, a series of curves were established, allowing the comparison of the temperature effect of successively deepening notches with a line having no reduction. It had been originally planned to use a 40°C. rise as an arbitrary upper limit for temperature increase, but it became apparent that tests should be performed to the point of destruction. (The point of destruction is defined as the point at which there is a separation of the copper from the base material due to heat developed by a current overload.) After temperature testing, pull tests were made on the individual circuit lines to determine at what point the temperature increase which developed at the point of reduction began to effect a degradation of the bond strength of the copper to the base laminate.

Temperature rise tests were also performed on production type circuit boards which had nicks, pin holes, and scratches in the circuit. The data on temperature rise versus current were recorded and a tentative design chart for determining current carrying capacity and temperature rise for 1 and 2 oz. copper was drawn.

A tentative non-destructive electrical test for evaluating the effect of nicks, pin holes and scratches on printed wiring boards is presented in Appendix A at the back of the report under a given set of electrical and physical conditions. This test will provide a standard for determining the degree of reduction which may be safely allowed per square, or per given length of conductor.

2.2 Specimen Fabrication

Artwork was produced for three types of test patterns which were printed and etched on various types of copper clad laminates. Each pattern was marked with letters A, B and C respectively. The three types of test patterns are illustrated in Figures 1, 2 and 3. The percent reduction of width for each conductor was measured at the notched area. (See Figures 1, 2 and 3.) The dimensions of each test pattern were checked on an optical comparator and it was established that the test patterns were within ±0.1 Mil of the required dimensions. The conductor width, at the notch area for each type of test pattern is given below:

PATTERN "A"

Strip No.	Conductor Width in Inches at Notch
1	0.100 (No reduction)
2	0.090 (10% reduction)
3	0.080 (20% reduction)
4	0.070 (30% reduction)
5	0.060 (40% reduction)
6	0.050 (50% reduction)

PATTERN "B"

Strip No.	Conductor Width in Inches at Notch
1	0.047 (no reduction)
2	0.035 (25% reduction)
3	0.024 (50% reduction)
4	0.020 (60% reduction)

PATTERN "C"

Strip No.	Conductor Width in Inches at Notch
1	0.047 (No reduction)
2	0.035 (25% reduction)
3	0.024 (50% reduction)
4	0.020 (60% reduction)

Pattern "C" has five individual notches in Strips 2, 3 and 4. (See Figure No. 3.) These additional notches in each strip of Pattern "C" were added to see what effect this might have on the temperature rise of each copper conductor.

The general procedures for printing and etching the test specimens are outlined in Appendix B of the report. After the boards have been prepared, as outlined in Appendix B,

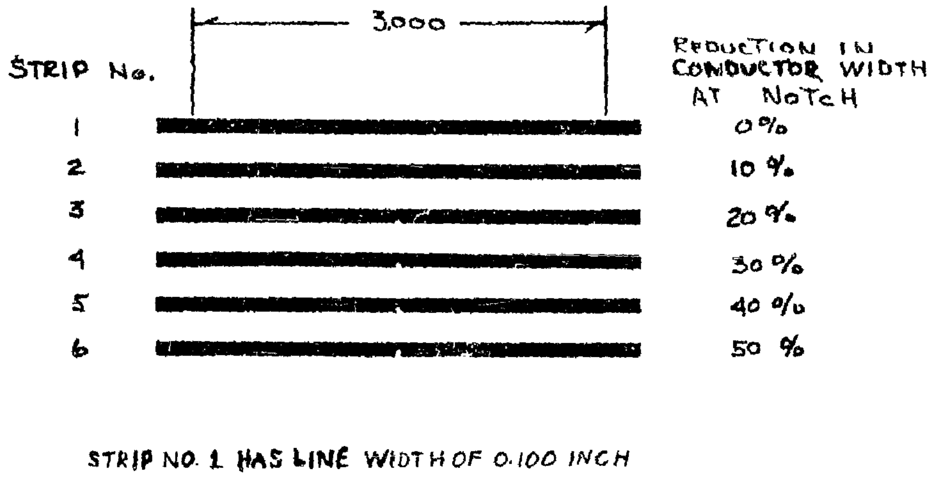


Figure No. 1. Test Pattern "A"

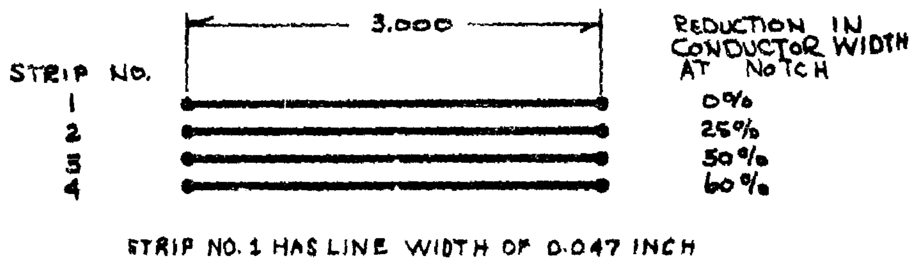


Figure No. 2. Test Pattern "B"

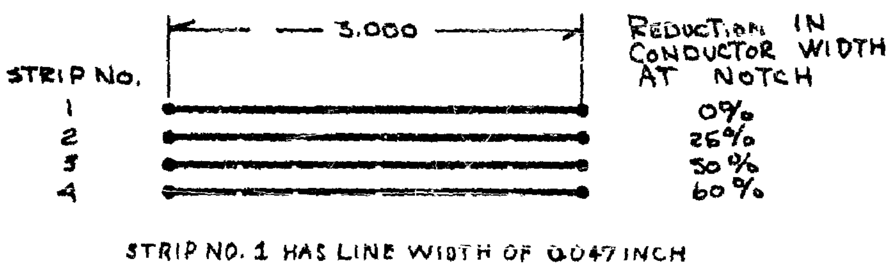


Figure No. 3. Test Pattern "C"

terminals were soldered to each copper strip of each test board. The distance between terminals was 3.000 inches. The cross-sectional area of the terminal chosen was large enough to carry the maximum current used during the temperature versus current measurments without effecting the results. The specimens were recleaned and bagged in a polyethylene bag after the terminals had been soldered in place.

Additional test specimens were produced where nicks, pin holes, and scratches were inscribed in several production type circuit patterns. The general printing and etching procedures for these test boards are outlined in Appendix B at the back of the report.

2.3 Measuring Equipment

The basic circuit layout for measuring temperature rise is illustrated in Figure No. 4. Figure No. 5 shows the completed test equipment set up for measuring temperature rise in a copper conductor. Figure No. 6 shows the test setup for testing test boards 15 to 21. The following equipment was used for measuring temperature rise:

1. Model 931 D. C. Ampere Meter
2. 20 Amp. Shunt
3. 8 Ohm. 50 Watt Rheostat
4. Two (125V-25Amp) Knife Switches
5. One 6 volt Battery (130 Ampere hours)
6. Fenwal Temperature Meter (Model 58301-5)
7. Thermistor Bead Sensing Device (Fenwal No. GB34P92)
8. TW #8 Solid Copper Wire
9. Universal Timer (Model 167)
10. Jagabi Carbon Pile Rheostat (Model #10-.018 to 1.8 ohms Resistance).

2.4 Testing Procedure

The following test procedures were used to collect experimental data on temperature rise versus current for test patterns A, B and C as illustrated in Figures 1, 2 and 3 of the report and test boards 15 through 21. The test board was placed in the sample holder and the two circuit wires with connectors were positioned on the respective terminals of the conductor to be tested. This can be seen in Figures No. 5 and 6.

The following test procedure was followed for test boards 1 through 14.

The thermistor bead sensing probe was placed in the middle of the conductor at the point of area reduction and secured with a plastic adhesive. While the adhesive was drying (20 minutes to dry), the Fenwal temperature meter was turned to on position to measure the ambient temperatures around the conductor test area. An 8 ohm rheostat was used in the circuit to better control the lower current range (1 to 5 amps). The ambient temperature was recorded and current was allowed to flow in the copper conductor. Temperature readings were taken at 1 ampere intervals.

It took 5 to 6 minutes for the current to stabilize before the temperature was recorded Measurements were made up to a temperature rise of 40°C above ambient. When the

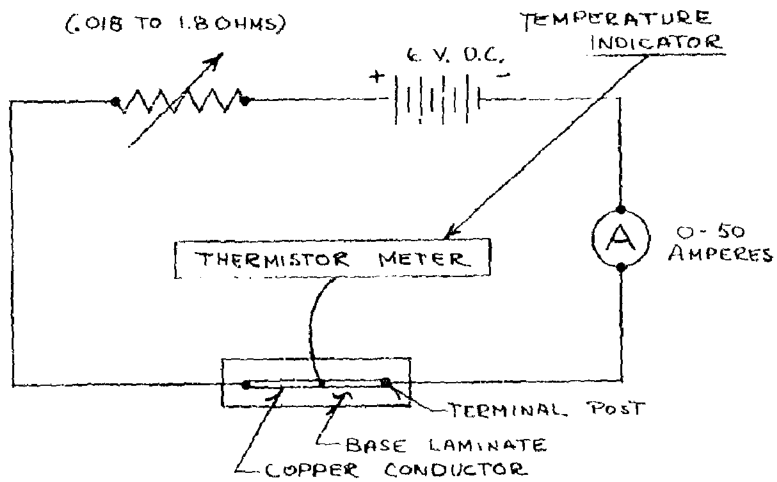


Figure No. 4 Basic Circuit For Measuring Temperature Rise In A Copper Conductor

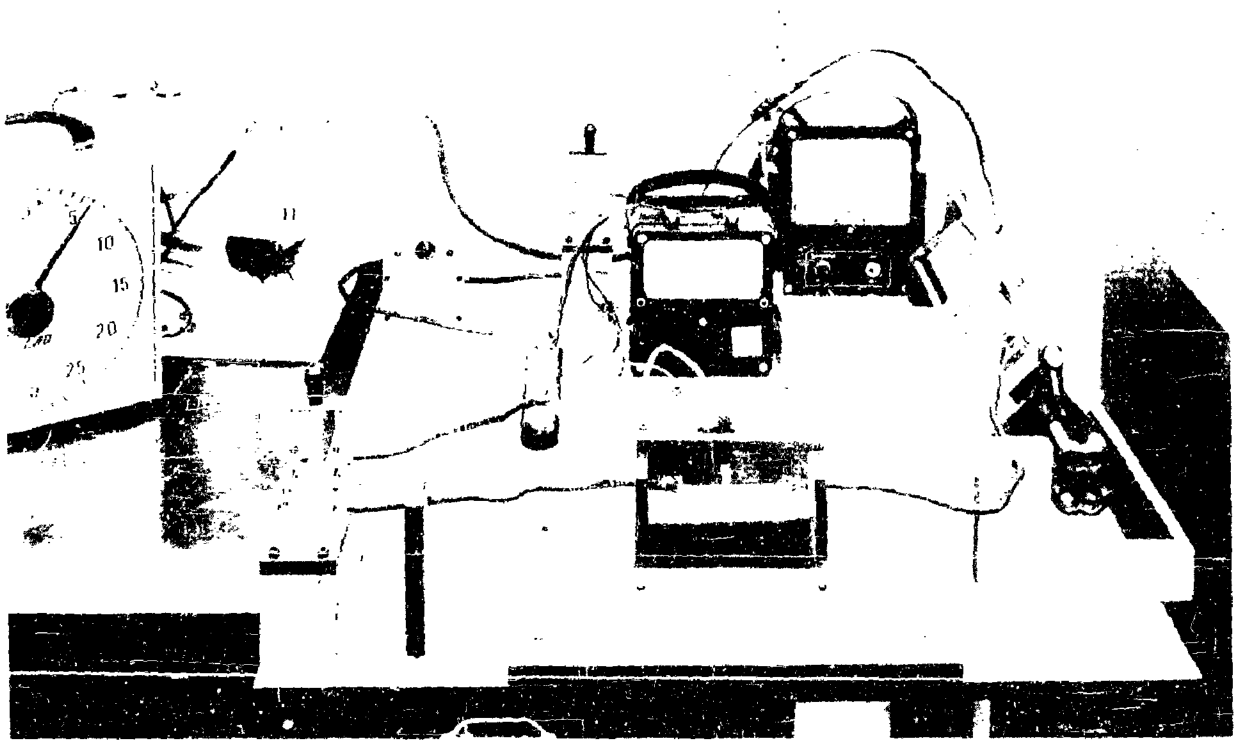


Figure No. 5. Test Set Up For Measuring Temperature Rise

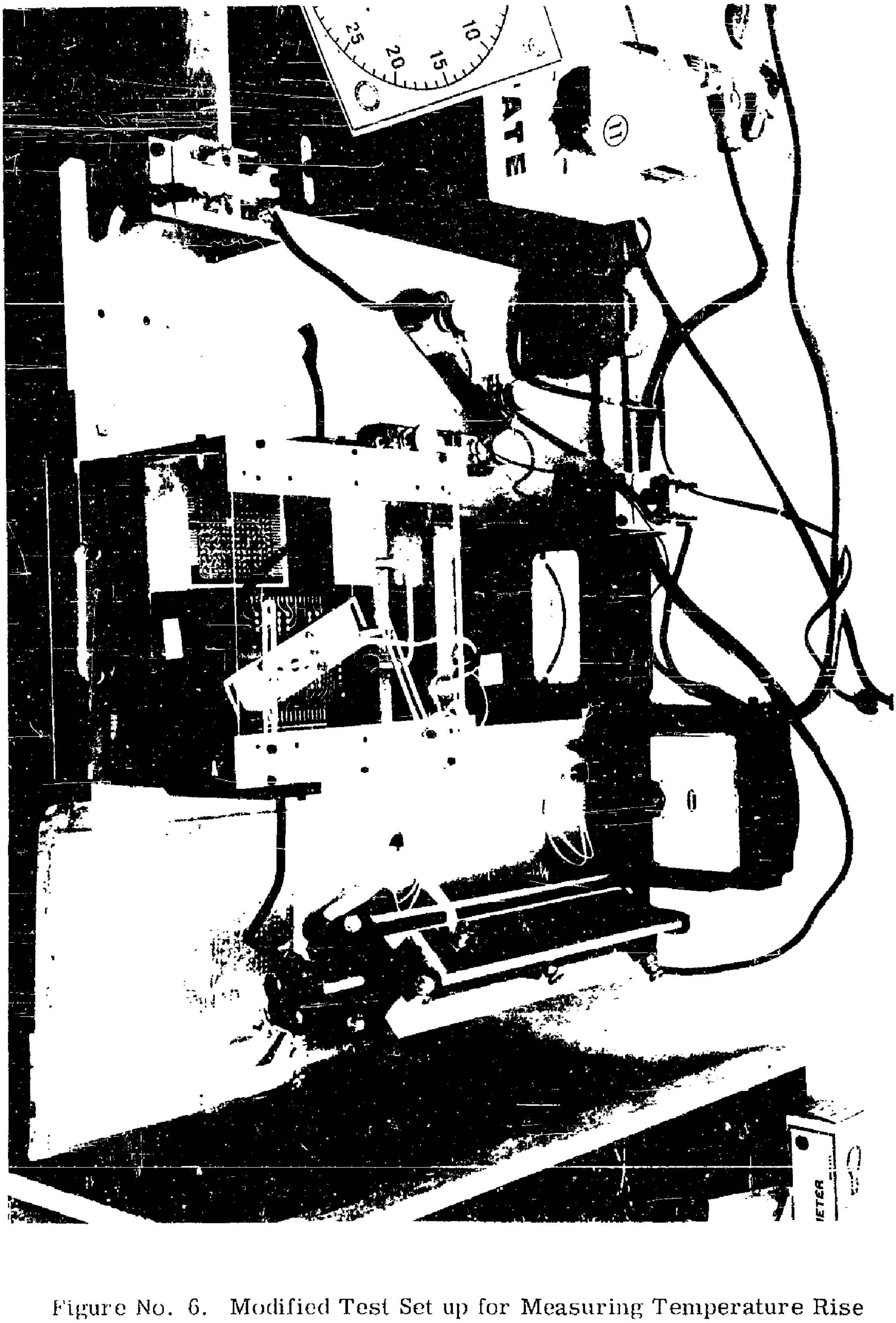


Figure No. 6. Modified Test Set up for Measuring Temperature Rise on Production Type Boards

measurements were completed on one conductor of pattern A, B or C (see Figures 1, 2 or 3), the thermistor probe was switched to the next conductor. The adhesive around the thermistor probe was removed by using methyl ethyl ketone solvent. The same procedure, as described above, was repeated on each successive conductor to be tested.

To obtain data on conductor lines or production type boards, the above testing procedure was altered to allow measurements regardless of conductor configuration. Test boards 15 through 21 were then tested by the following procedure.

The degree of cross-section area reduction was established for nicks or pin holes by physical measurement of the reduced area on an optical comparator. The area reduction generated by a scratch was established by measuring the width of the scratch on the comparator, and the depth using a sharp pointed probe on a dial indicator with a surface plate and height gage.

The test board was then placed in the specimen holder. (See Figure No. 8.) The thermistor bead was put in the thermister bead holding device as shown in Figure No. 7. This holding device enabled the thermistor bead to be positioned at any desired point on the test board where a temperature measurement was to be made, and was designed to insure firm contact with the surface of the conductor. After the thermister bead was positioned at the desired measuring point on the conductor, the two electrode wire connectors were positioned on both sides of the thermistor bead. (Distance between electrodes varied between 0.750 inch to 1.50 inches.) Figure No. 9 shows the high current terminal that was used as electrodes. A visual inspection was made to see that proper physical contact was made between electrodes and the surface of the copper conductor. From this point the testing procedure was performed in the same manner as the test procedure for test boards 1 through 14, except that the application of a plastic adhesive was not necessary because of the thermistor bead holding device which supported and held the bead itself. (See Figure No. 7.)

2.5 Analysis of Temperature Rise Measurements

Fourteen test boards were tested and data collected and presented in Tables I to XIV. The temperature versus current data is plotted and reported in Figures 10 to 31. The test time reported in Tables I to XIV refers to the time required for each temperature to stabilize.

The tabular and graphical data reported on the fourteen test boards include the following types of base laminates, copper weight and type of test pattern used on each test board.

Test Board No.	Base Laminate	Laminate Thickness	Approx. Weight	Test Pattern
1	Paper Phenolic (PP)	1/16 in.	1 oz.	A
2	Paper Phenolic (PP)	1/8 in.	1 oz.	A
3	Paper Phenolic (PP)	1/8 in.	2 oz.	A
4	Paper Epoxy (PX)	1/16 in.	1 oz.	A
5	Paper Epoxy (PX)	1/8 in.	1 oz.	A
6	Paper Epoxy (PX)	1/8 in.	2 oz.	A

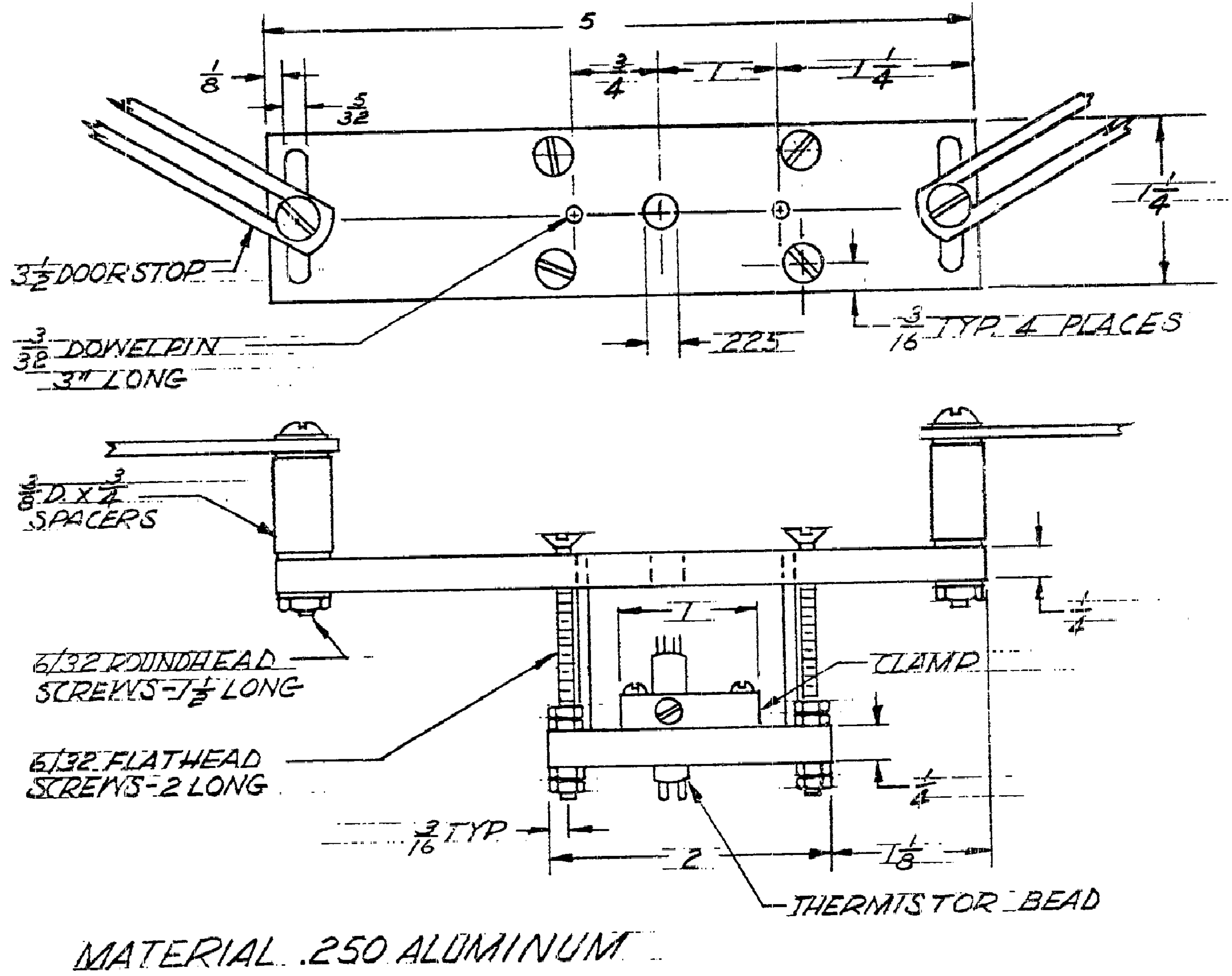


Figure No. 7. Thermistor Bead Holding Device

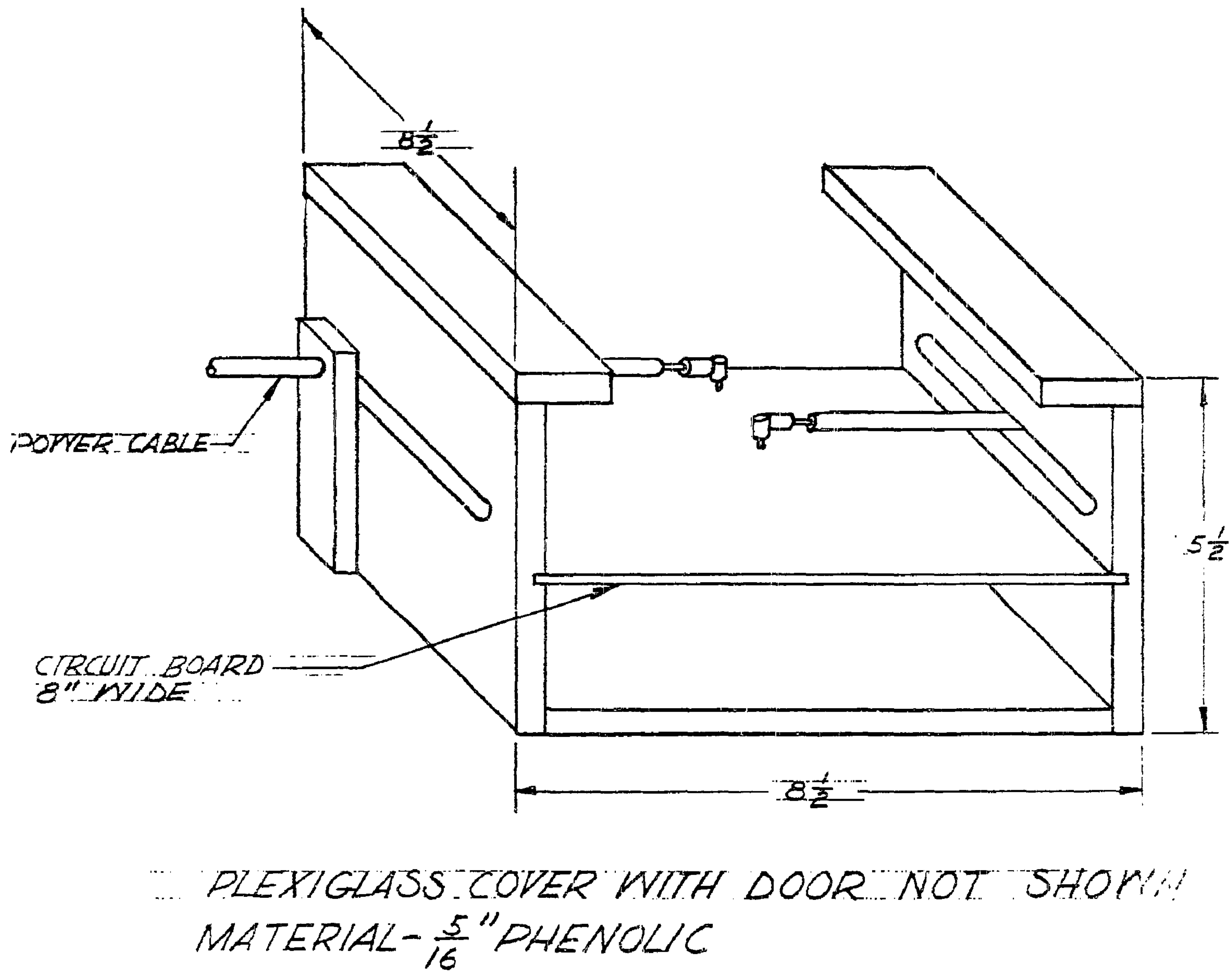


Figure No. 8. Temperature Rise Test Chamber

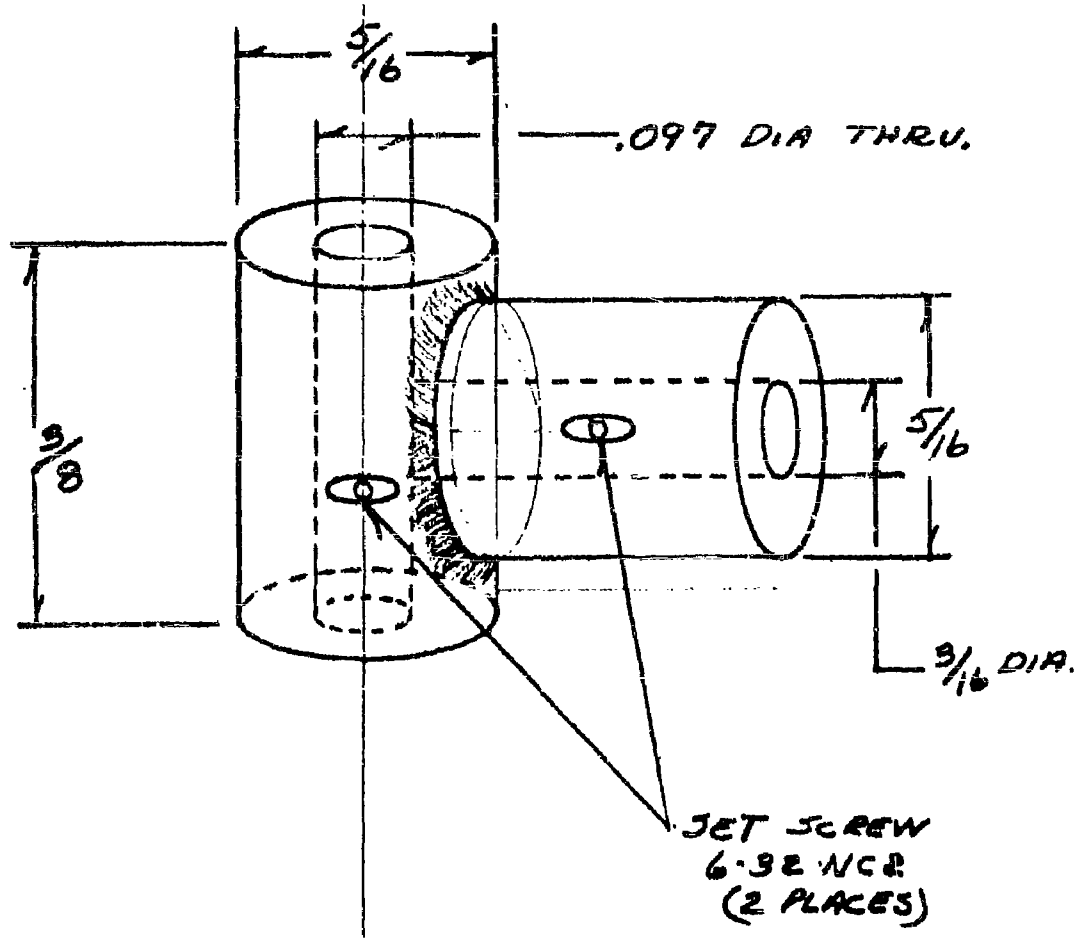


Figure No. 9. High Current Termination Terminal

TABLE I

DATA SHEET - TEMPERATURE VS CURRENT ON PAPER PHENOLIC (1/16 INCH THICKNESS - 1 OZ) COPPER[1]

Test Board No.	Type of Base Laminate	Laminate Thickness (Inch)	Copper Foil Weight (OZ)	Conductor Width (Inch)	Ampere I (Amps.)	Test Time (Minutes)	Temperature ^{o}F Reduction of Cross Sectional Area of Conductor					
							None	10%	20%	30%	40%	50%
1	Paper Phenolic (XXXP)	1/16	1	0.100	0	0	79.0	80.5	78.0	77.0	77.5	79.5
1	Paper Phenolic (XXXP)	1/16	1	0.100	1	6.0	80.5	82.0	79.5	80.0	78.0	81.0
1	Paper Phenolic (XXXP)	1/16	1	0.100	2	6.0	83.5	84.5	83.5	82.5	80.5	84.0
1	Paper Phenolic (XXXP)	1/16	1	0.100	3	6.0	89.5	89.5	89.5	87.5	84.5	89.5
1	Paper Phenolic (XXXP)	1/16	1	0.100	4	6.0	96.0	96.5	98.5	94.5	92.0	97.0
1	Paper Phenolic (XXXP)	1/16	1	0.100	5	6.0	105.	105.5	109.5	103.5	101.5	106.5
1	Paper Phenolic (XXXP)	1/16	1	0.100	6	6.0	117.5	116.5	121.5	114.5	114.0	118.5
1	Paper Phenolic (XXXP)	1/16	1	0.100	7	6.0	129.5	129.0	135.0	127.5	127.5	132.0
1	Paper Phenolic (XXXP)	1/16	1	0.100	8	6.0	145.5	146.0	153.0	144.0	146.0	150.0
1	Paper Phenolic (XXXP)	1/16	1	0.100	9	6.0	164.0	164.0	173.5	163.0	164.5	169.5

1 Test Pattern "A"

TABLE II

1

DATA SHEET - TEMPERATURE VS CURRENT ON PAPER PHENOLIC (1/8 INCH THICKNESS - 1 OZ) COPPER

Test Board No.	Type of Base Laminate	Laminate Thickness (Inch)	Copper Foil Weight (OZ)	Conductor Width (Inch)	Ampere I (Amps.)	Test Time (Minutes)	Temperature ^{o}F					
							Reduction of Cross Sectional Area of Conductor					
							None	10%	20%	30%	40%	50%
2	Paper Phenolic (XXXP)	1/8	1	0.100	0	0	77.5	76.0	75.0	79.5	76.0	76.5
2	Paper Phenolic (XXXP)	1/8	1	0.100	1	5.5	79.5	77.0	76.5	80.0	78.0	78.0
2	Paper Phenolic (XXXP)	1/8	1	0.100	2	5.5	82.0	79.5	79.0	82.5	80.0	80.5
2	Paper Phenolic (XXXP)	1/8	1	0.100	3	5.5	86.0	83.0	83.5	86.0	84.0	84.5
2	Paper Phenolic (XXXP)	1/8	1	0.100	4	5.5	92.5	89.5	89.5	92.5	90.5	91.5
2	Paper Phenolic (XXXP)	1/8	1	0.100	5	5.5	100.5	96.5	97.0	100.5	98.5	100.5
2	Paper Phenolic (XXXP)	1/8	1	0.100	6	5.5	111.5	107.5	107.5	111.0	108.5	112.0
2	Paper Phenolic (XXXP)	1/8	1	0.100	7	5.5	123.5	120.0	120.0	123.0	122.0	124.0
2	Paper Phenolic (XXXP)	1/8	1	0.100	8	5.5	138.0	133.5	134.5	138.0	136.0	140.0
2	Paper Phenolic (XXXP)	1/8	1	0.100	9	5.5	154.0	151.5	152.5	156.0	154.0	160.0
2	Paper Phenolic (XXXP)	1/8	1	0.100	10	5.5	172.5	172.0	174.0	178.0	176.0	175.0

1 Test Pattern "A"

TABLE III

DATA SHEET - TEMPERATURE VS CURRENT ON PAPER PHENOLIC (1/8 INCH THICKNESS - 2 OZ) COPPER[1]

Test Board No.	Type of Base Laminate	Laminate Thickness (Inch)	Copper Foil Weight (OZ)	Conductor Width (Inch)	Ampere I (Amps.)	Test Time (Minutes)	Temperature °F — Reduction of Cross Sectional Area of Conductor: None	10%	20%	30%	40%	50%
3	Paper Phenolic (XXXP)	1/8	2	0.100	0	0	79.0	83.0	81.0	80.0	81.0	78.0
3	Paper Phenolic (XXXP)	1/8	2	0.100	1	5.5	80.0	83.5	81.5	80.5	81.5	78.5
3	Paper Phenolic (XXXP)	1/8	2	0.100	2	5.5	81.0	84.5	82.0	82.0	84.0	79.5
3	Paper Phenolic (XXXP)	1/8	2	0.100	3	5.5	82.0	86.0	84.0	83.5	85.5	81.5
3	Paper Phenolic (XXXP)	1/8	2	0.100	4	5.5	84.0	88.0	86.0	86.0	88.0	84.5
3	Paper Phenolic (XXXP)	1/8	2	0.100	5	5.5	86.0	90.0	89.5	89.5	90.5	88.5
3	Paper Phenolic (XXXP)	1/8	2	0.100	6	5.5	90.0	93.5	93.0	94.0	95.0	93.0
3	Paper Phenolic (XXXP)	1/8	2	0.100	7	5.5	95.0	97.5	98.0	98.0	100.0	99.0
3	Paper Phenolic (XXXP)	1/8	2	0.100	8	5.5	100.5	103.0	103.5	104.0	105.5	106.0
3	Paper Phenolic (XXXP)	1/8	2	0.100	9	5.5	108.0	109.5	110.0	111.5	112.5	113.0
3	Paper Phenolic (XXXP)	1/8	2	0.100	10	5.5	115.0	118.0	117.5	120.0	121.0	120.0
3	Paper Phenolic (XXXP)	1/8	2	0.100	11	5.5	122.0	126.0	124.0	128.0	129.5	132.0
3	Paper Phenolic (XXXP)	1/8	2	0.100	12	5.5	132.0	135.5	136.0	140.0	140.5	144.0

1 Test Pattern "A"

TABLE III (CONT)

DATA SHEET - TEMPERATURE VS CURRENT ON PAPER PHENOLIC (1/8 INCH THICKNESS - 2 OZ) COPPER [1]

Test Board No.	Type of Base Laminate	Laminate Thickness (Inch)	Copper Foil Weight (OZ)	Conductor Width (Inch)	Ampere I (Amps.)	Test Time (Minutes)	Temperature °F — Reduction of Cross Sectional Area of Conductor: None	10%	20%	30%	40%	50%
3	Paper Phenolic (XXXP)	1/8	2	0.100	13	5.5	144.0	145.0	147.0	151.0	149.5	156.0
3	Paper Phenolic (XXXP)	1/8	2	0.100	14	5.5	154.5	152.0	159.5	160.0	160.0	161.5
3	Paper Phenolic (XXXP)	1/8	2	0.100	15	5.5	164.0	163.0	--	--	--	--

1 Test Pattern "A"

TABLE IV

DATA SHEET - TEMPERATURE VS CURRENT ON PAPER EPOXY (1/16 INCH THICKNESS - 1 OZ) COPPER [1]

Test Board No.	Type of Base Laminate	Laminate Thickness (Inch)	Copper Foil Weight (OZ)	Conductor Width (Inch)	Ampere I (Amps.)	Test Time (Minutes)	Temperature °F — Reduction of Cross Sectional Area of Conductor: None	10%	20%	30%	40%	50%
4	Paper Epoxy (PX)	1/16	1	0.100	0	0	80.0	80.5	78.0	80.5	76.0	77.0
4	Paper Epoxy (PX)	1/16	1	0.100	1	6.0	81.0	81.5	78.5	81.0	77.0	78.0
4	Paper Epoxy (PX)	1/16	1	0.100	2	6.0	84.0	85.5	82.0	83.0	80.5	81.0
4	Paper Epoxy (PX)	1/16	1	0.100	3	6.0	88.5	90.0	88.0	86.0	85.0	85.0
4	Paper Epoxy (PX)	1/16	1	0.100	4	6.0	95.0	98.0	95.5	92.0	91.5	92.0
4	Paper Epoxy (PX)	1/16	1	0.100	5	6.0	104.0	105.0	104.0	100.0	101.0	100.0
4	Paper Epoxy (PX)	1/16	1	0.100	6	6.0	113.5	116.0	114.0	110.0	112.0	110.5
4	Paper Epoxy (PX)	1/16	1	0.100	7	6.0	125.0	128.0	125.5	120.0	124.0	124.0
4	Paper Epoxy (PX)	1/16	1	0.100	8	6.0	139.5	142.5	139.5	135.0	141.0	140.0
4	Paper Epoxy (PX)	1/16	1	0.100	9	6.0	158.0	160.0	153.5	156.0	168.0	160.0

1 Test Pattern "A"

TABLE V

DATA SHEET [1] TEMPERATURE VS CURRENT ON PAPER EPOXY (1/8 INCH THICKNESS - 1 OZ) COPPER

Test Board No.	Type of Base Laminate	Laminate Thickness (Inch)	Copper Foil Weight (OZ)	Conductor Width (Inch)	Ampere I (Amps.)	Test Time (Minutes)	Temperature °F Reduction of Cross Sectional Area of Conductor					
							None	10%	20%	30%	40%	50%
5	Paper Epoxy (PX)	1/8	1	0.100	0	0	75.0	82.0	80.0	78.0	78.0	74.0
5	Paper Epoxy (PX)	1/8	1	0.100	1	6.5	76.0	82.5	81.0	80.0	79.0	76.0
5	Paper Epoxy (PX)	1/8	1	0.100	2	6.5	78.0	83.5	82.0	82.0	80.5	78.5
5	Paper Epoxy (PX)	1/8	1	0.100	3	6.5	81.5	86.0	85.0	84.0	84.0	82.0
5	Paper Epoxy (PX)	1/8	1	0.100	4	6.5	86.5	89.0	90.0	88.5	88.0	88.0
5	Paper Epoxy (PX)	1/8	1	0.100	5	6.5	93.5	93.0	96.0	96.0	94.5	96.0
5	Paper Epoxy (PX)	1/8	1	0.100	6	6.5	102.0	101.0	101.0	102.0	101.5	104.0
5	Paper Epoxy (PX)	1/8	1	0.100	7	6.5	111.0	106.0	113.0	112.5	110.0	112.0
5	Paper Epoxy (PX)	1/8	1	0.100	8	6.5	123.0	114.0	125.0	124.5	122.0	126.0
5	Paper Epoxy (PX)	1/8	1	0.100	9	6.5	135.0	131.0	133.0	136.0	133.0	140.5
5	Paper Epoxy (PX)	1/8	1	0.100	10	6.5	149.5	148.0	151.0	152.0	150.5	155.0
5	Paper Epoxy (PX)	1/8	1	0.100	11	6.5	159.5	167.0	164.0	168.0	158.0	169.0

1 Test Pattern "A"

TABLE VI

DATA SHEET - TEMPERATURE VS CURRENT ON PAPER EPOXY (1/8 INCH THICKNESS - 2 OZ) COPPER [1]

Test Board No.	Type of Base Laminate	Laminate Thickness (Inch)	Copper Foil Weight (OZ)	Conductor Width (Inch)	Ampere I (Amps.)	Test Time (Minutes)	Temperature °F — Reduction of Cross Sectional Area of Conductor: None	10%	20%	30%	40%	50%
6	Paper Epoxy (PX)	1/8	2	0.100	0	0	80.0	80.0	79.5	78.0	78.0	76.5
6	Paper Epoxy (PX)	1/8	2	0.100	1	6.0	80.0	80.5	80.0	79.0	78.5	77.5
6	Paper Epoxy (PX)	1/8	2	0.100	2	6.0	81.0	81.5	80.5	79.5	80.0	79.0
6	Paper Epoxy (PX)	1/8	2	0.100	3	6.0	82.5	83.0	82.0	80.5	80.5	81.0
6	Paper Epoxy (PX)	1/8	2	0.100	4	6.0	85.5	86.0	84.5	82.5	84.5	84.5
6	Paper Epoxy (PX)	1/8	2	0.100	5	6.0	89.0	89.5	88.0	85.5	88.5	88.5
6	Paper Epoxy (PX)	1/8	2	0.100	6	6.0	94.0	93.5	92.0	90.0	93.5	94.0
6	Paper Epoxy (PX)	1/8	2	0.100	7	6.0	99.0	99.0	97.0	94.5	99.5	100.5
6	Paper Epoxy (PX)	1/8	2	0.100	8	6.0	105.5	105.0	103.0	102.5	106.0	108.0
6	Paper Epoxy (PX)	1/8	2	0.100	9	6.0	113.0	111.5	110.0	110.0	113.5	116.0
6	Paper Epoxy (PX)	1/8	2	0.100	10	6.0	121.5	120.0	118.0	119.0	122.5	124.0
6	Paper Epoxy (PX)	1/8	2	0.100	11	6.0	133.0	128.5	127.0	128.0	132.0	133.5
6	Paper Epoxy (PX)	1/8	2	0.100	12	6.0	143.0	139.5	137.5	139.5	144.0	145.5

1 Test Pattern "A"

TABLE VI (CONT)

DATA SHEET - TEMPERATURE VS CURRENT ON PAPER EPOXY (1/8 INCH THICKNESS - 2 OZ) COPPER[1]

Test Board No.	Type of Base Laminate	Laminate Thickness (Inch)	Copper Foil Weight (OZ)	Conductor Width (Inch)	Ampere I (Amps.)	Test Time (Minutes)	Temperature ^{o}F Reduction of Cross Sectional Area of Conductor: None	10%	20%	30%	40%	50%
6	Paper Epoxy (PX)	1/8	2	0.100	13	6.0	154.0	150.5	149.0	149.0	157.5	158.0
6	Paper Epoxy (PX)	1/8	2	0.100	14	6.0	167.5	163.5	163.0	164.0	169.0	168.0

1 Test Pattern "A"

TABLE VII

DATA SHEET[1] - TEMPERATURE VS CURRENT ON GLASS EPOXY (1/8 INCH THICKNESS - 2 OZ) COPPER

Test Board No.	Type of Base Laminate	Laminate Thickness (Inch)	Copper Foil Weight (OZ)	Conductor Width (Inch)	Ampere I (Amps.)	Test Time (Minutes)	Temperature °F — Reduction of Cross Sectional Area of Conductor: None	10%	20%	30%	40%	50%
7	Glass Epoxy (GE)	1/8	2	0.100	0	0	81.5	82.0	80.0	77.0	85.0	77.5
7	Glass Epoxy (GE)	1/8	2	0.100	1	5.0	82.0	82.5	82.0	77.5	85.5	78.0
7	Glass Epoxy (GE)	1/8	2	0.100	2	5.0	82.5	83.0	84.0	78.5	86.0	78.5
7	Glass Epoxy (GE)	1/8	2	0.100	3	5.0	83.5	84.5	85.0	85.0	86.5	79.5
7	Glass Epoxy (GE)	1/8	2	0.100	4	5.0	85.0	86.0	86.0	81.5	87.5	81.0
7	Glass Epoxy (GE)	1/8	2	0.100	5	5.0	87.0	88.0	87.0	83.5	90.0	83.0
7	Glass Epoxy (GE)	1/8	2	0.100	6	5.0	89.5	90.0	88.0	86.0	92.0	85.5
7	Glass Epoxy (GE)	1/8	2	0.100	7	5.0	92.0	93.0	89.0	89.0	94.5	89.0
7	Glass Epoxy (GE)	1/8	2	0.100	8	5.0	95.5	96.5	93.0	92.0	98.0	92.0
7	Glass Epoxy (GE)	1/8	2	0.100	9	5.0	100.0	101.0	95.0	96.0	101.5	96.0
7	Glass Epoxy (GE)	1/8	2	0.100	10	5.0	104.5	104.5	102.0	101.0	106.0	101.5

1 Test Pattern "A"

TABLE VII (CONT)

DATA SHEET - TEMPERATURE VS CURRENT ON GLASS EPOXY (1/8 INCH THICKNESS - 2 OZ) COPPER [1]

Test Board No.	Type of Base Laminate	Laminate Thickness (Inch)	Copper Foil Weight (OZ)	Conductor Width (Inch)	Ampere I (Amps.)	Test Time (Minutes)	Temperature °F — Reduction of Cross Sectional Area of Conductor: None	10%	20%	30%	40%	50%
7	Glass Epoxy (GE)	1/8	2	0.100	11	5.0	109.5	109.5	104.0	106.0	110.5	106.5
7	Glass Epoxy (GE)	1/8	2	0.100	12	5.0	116.0	114.5	113.0	111.5	116.0	112.5
7	Glass Epoxy (GE)	1/8	2	0.100	13	5.0	122.0	120.5	119.0	119.5	122.0	119.0
7	Glass Epoxy (GE)	1/8	2	0.100	14	5.0	--	--	--	--	--	--
7	Glass Epoxy (GE)	1/8	2	0.100	15	5.0	135.5	131.5	130.0	130.0	132.5	152.0
7	Glass Epoxy (GE)	1/8	2	0.100	17	5.0	152.5	147.0	146.0	146.0	147.5	148.5
7	Glass Epoxy (GE)	1/8	2	0.100	19	5.0	172.0	164.0	163.0	164.0	168.0	169.0

1 Test Pattern "A"

TABLE VIII

DATA SHEET - TEMPERATURE VS CURRENT ON GLASS SILICONE (1/8 INCH THICKNESS - 2 OZ) COPPER [1]

Test Board No.	Type of Base Laminate	Laminate Thickness (Inch)	Copper Foil Weight (OZ)	Conductor Width (Inch)	Ampere I (Amps.)	Test Time (Minutes)	Temperature °F — Reduction of Cross Sectional Area of Conductor: None	10%	20%	30%	40%	50%
8	Glass Silicone (GS)	1/8	2	0.100	0	0	79.0	79.0	79.0	79.0	79.0	79.0
8	Glass Silicone (GS)	1/8	2	0.100	1	6.5	81.5	79.5	80.0	82.0	80.0	80.5
8	Glass Silicone (GS)	1/8	2	0.100	2	6.5	82.0	80.0	80.5	82.5	81.0	81.0
8	Glass Silicone (GS)	1/8	2	0.100	3	6.5	83.5	82.0	82.0	84.0	82.5	82.5
8	Glass Silicone (GS)	1/8	2	0.100	4	6.5	86.0	84.5	85.0	86.5	85.5	85.0
8	Glass Silicone (GS)	1/8	2	0.100	5	6.5	89.5	87.5	88.0	90.0	88.5	88.5
8	Glass Silicone (GS)	1/8	2	0.100	6	6.5	94.0	91.5	92.5	95.0	92.5	92.0
8	Glass Silicone (GS)	1/8	2	0.100	7	6.5	98.5	96.5	98.0	100.0	96.0	97.0
8	Glass Silicone (GS)	1/8	2	0.100	8	6.5	104.5	102.0	104.0	106.5	101.5	103.0
8	Glass Silicone (GS)	1/8	2	0.100	9	6.5	112.0	109.0	111.5	114.0	108.0	110.0
8	Glass Silicone (GS)	1/8	2	0.100	10	6.5	120.0	118.0	120.0	122.0	116.5	117.0

1 Test Pattern "A"

TABLE VIII (CONT)

DATA SHEET - TEMPERATURE VS CURRENT ON GLASS SILICONE (1/8 INCH THICKNESS - 2 OZ) COPPER [1]

Test Board No.	Type of Base Laminate	Laminate Thickness (Inch)	Copper Foil Weight (OZ)	Conductor Width (Inch)	Ampere I (Amps.)	Test Time (Minutes)	Temperature °F — Reduction of Cross Sectional Area of Conductor: None	10%	20%	30%	40%	50%
8	Glass Silicone (GS)	1/8	2	0.100	11	6.5	128.0	125.0	129.0	129.0	125.0	126.5
8	Glass Silicone (GS)	1/8	2	0.100	12	6.5	138.0	135.5	140.0	142.0	135.5	136.0
8	Glass Silicone (GS)	1/8	2	0.100	13	6.5	148.5	146.5	151.0	153.0	146.5	148.0
8	Glass Silicone (GS)	1/8	2	0.100	14	6.5	160.0	159.0	164.5	167.0	159.0	158.0

1 Test Pattern "A"

TABLE IX

DATA SHEET - TEMPERATURE VS CURRENT ON PAPER EPOXY (1/8 INCH THICKNESS - 1 OZ) COPPER [1]

Test Board No.	Type of Base Laminate	Laminate Thickness (Inch)	Copper Foil Weight (OZ)	Conductor Width (Inch)	Ampere I (Amps.)	Test Time (Minutes)	Temperature ^{o}F — Reduction of Cross Sectional Area of Conductor: None	25%	50%	60%
9	Paper Epoxy (PX)	1/8	1	0.047	0	0	76.5	81.0	79.5	85.5
9	Paper Epoxy (PX)	1/8	1	0.047	1	6.0	77.5	83.0	80.5	86.5
9	Paper Epoxy (PX)	1/8	1	0.047	2	6.0	82.5	88.5	85.5	91.5
9	Paper Epoxy (PX)	1/8	1	0.047	3	6.0	92.0	99.0	96.0	102.0
9	Paper Epoxy (PX)	1/8	1	0.047	4	6.0	109.5	115.0	112.5	120.0
9	Paper Epoxy (PX)	1/8	1	0.047	5	6.0	129.5	136.5	133.0	141.0
9	Paper Epoxy (PX)	1/8	1	0.047	6	6.0	158.0	164.5	161.0	171.0

1 Test Pattern "B"

TABLE X

DATA SHEET - TEMPERATURE VS CURRENT ON PAPER EPOXY (1/8 INCH THICKNESS - 1 OZ) COPPER[1]

Test Board No.	Type of Base Laminate	Laminate Thickness (Inch)	Copper Foil Weight (OZ)	Conductor Width (Inch)	Ampere I (Amps.)	Test Time (Minutes)	Temperature °F — Reduction of Cross Sectional Area of Conductor: None	25%	50%	60%
10	Paper Epoxy (PX)	1/8	1	0.047	0	0	76.5	84.5	84.5	83.5
10	Paper Epoxy (PX)	1/8	1	0.047	1	5.5	77.5	86.0	86.5	85.0
10	Paper Epoxy (PX)	1/8	1	0.047	2	5.5	82.5	91.0	92.5	90.5
10	Paper Epoxy (PX)	1/8	1	0.047	3	5.5	92.0	101.5	103.5	102.0
10	Paper Epoxy (PX)	1/8	1	0.047	4	5.5	109.5	116.0	121.5	119.0
10	Paper Epoxy (PX)	1/8	1	0.047	5	5.5	129.5	134.0	144.5	139.0
10	Paper Epoxy (PX)	1/8	1	0.047	6	5.5	158.0	162.0	175.0	169.0

1 Test Pattern "C"

TABLE XI

DATE SHEET - TEMPERATURE VS CURRENT ON PAPER EPOXY (1/8 INCH THICKNESS - 2 OZ) COPPER [1]

Test Board No.	Type of Base Laminate	Laminate Thickness (Inch)	Copper Foil Weight (OZ)	Conductor Width (Inch)	Ampere I (Amps.)	T t Time (Minutes)	Temperature °F Reduction of Cross Sectional Area of Conductor None	25%	50%	60%
11	Paper Epoxy (PX)	1/8	2	0.047	0	0	79.0	79.5	78.5	80.5
11	Paper Epoxy (PX)	1/8	2	0.047	1	5.0	79.5	80.5	79.5	81.5
11	Paper Epoxy (PX)	1/8	2	0.047	2	5.0	82.0	82.5	82.0	84.0
11	Paper Epoxy (PX)	1/8	2	0.047	3	5.0	86.0	87.0	86.5	88.0
11	Paper Epoxy (PX)	1/8	2	0.047	4	5.0	93.0	93.0	93.0	95.0
11	Paper Epoxy (PX)	1/8	2	0.047	5	5.0	102.0	101.0	101.0	103.5
11	Paper Epoxy (PX)	1/8	2	0.047	6	5.0	113.0	114.5	112.0	115.5
11	Paper Epoxy (PX)	1/8	2	0.047	7	5.0	127.5	124.5	125.0	128.0
11	Paper Epoxy (PX)	1/8	2	0.047	8	5.0	143.0	139.5	142.0	146.0
11	Paper Epoxy (PX)	1/8	2	0.047	9	5.0	162.5	158.0	163.0	166.5

1 Test Pattern "B"

TABLE XII

DATA SHEET - TEMPERATURE VS CURRENT ON PAPER EPOXY (1/8 INCH THICKNESS - 2 OZ) COPPER [1]

Test Board No.	Type of Base Laminate	Laminate Thickness (Inch)	Copper Foil Weight (OZ)	Conductor Width (Inch)	Ampere I (Amps.)	Test Time (Minutes)	Temperature °F Reduction of Cross Sectional Area of Conductor			
							None	25%	50%	60%
12	Paper Epoxy (PX)	1/8	2	0.047	0	0	79.0	Note 2	80.0	Note 2
12	Paper Epoxy (PX)	1/8	2	0.047	1	5.0	79.5	----	81.0	----
12	Paper Epoxy (PX)	1/8	2	0.047	2	5.0	82.0	----	83.5	----
12	Paper Epoxy (PX)	1/8	2	0.047	3	5.0	86.0	----	89.0	----
12	Paper Epoxy (PX)	1/8	2	0.047	4	5.0	93.0	----	97.0	----
12	Paper Epoxy (PX)	1/8	2	0.047	5	5.0	102.0	----	108.0	----
12	Paper Epoxy (PX)	1/8	2	0.047	6	5.0	113.0	----	121.5	----
12	Paper Epoxy (PX)	1/8	2	0.047	7	5.0	127.5	----	136.5	----
12	Paper Epoxy (PX)	1/8	2	0.047	8	5.0	143.0	----	156.5	----
12	Paper Epoxy (PX)	1/8	2	0.047	9	5.0	162.5	----	180.0	----

1 Test Pattern "C"

2 These conductor strips were damaged so were not tested

TABLE XIII

DATA SHEET - TEMPERATURE VS CURRENT ON GLASS SILICONE (1/8 INCH THICKNESS - 2 OZ) COPPER[1]

Test Board No.	Type of Base Laminate	Laminate Thickness (Inch)	Copper Foil Weight (OZ)	Conductor Width (Inch)	Ampere I (Amps.)	Test Time (Minutes)	Temperature °F — Reduction of Cross Sectional Area of Conductor: None	25%	50%	60%
13	Glass Silicone (GS)	1/8	2	0.047	0	0	82.0	80.0	75.0	83.0
13	Glass Silicone (GS)	1/8	2	0.047	1	5.0	83.0	81.0	76.5	84.0
13	Glass Silicone (GS)	1/8	2	0.047	2	5.0	85.5	82.5	79.5	86.0
13	Glass Silicone (GS)	1/8	2	0.047	3	5.0	89.5	86.5	82.5	90.0
13	Glass Silicone (GS)	1/8	2	0.047	4	5.0	95.0	92.0	88.5	97.0
13	Glass Silicone (GS)	1/8	2	0.047	5	5.0	103.0	100.0	96.5	105.5
13	Glass Silicone (GS)	1/8	2	0.047	6	5.0	112.0	109.0	106.5	116.5
13	Glass Silicone (GS)	1/8	2	0.047	7	5.0	122.5	120.0	120.0	128.5
13	Glass Silicone (GS)	1/8	2	0.047	8	5.0	136.0	134.0	139.0	146.0
13	Glass Silicone (GS)	1/8	2	0.047	9	5.0	152.5	152.0	154.0	165.5
13	Glass Silicone (GS)	1/8	2	0.047	10	5.0	171.0	172.0	176.0	181.0

1 Test Pattern "B"

TABLE XIV

DATA SHEET - TEMPERATURE VS CURRENT ON GLASS SILICONE (1/8 INCH THICKNESS - 2 OZ) COPPER [1]

Test Board No.	Type of Base Laminate	Laminate Thickness (Inch)	Copper Foil Weight (OZ)	Conductor Width (Inch)	Ampere I (Amps.)	Test Time (Minutes)	Temperature °F Reduction of Cross Sectional Area of Conductor None	25%	50%	60%
14	Glass Silicone (GS)	1/8	2	0.047	0	0	82.0	81.0	84.5	81.5
14	Glass Silicone (GS)	1/8	2	0.047	1	5.0	83.0	82.0	85.5	82.5
14	Glass Silicone (GS)	1/8	2	0.047	2	5.0	85.5	84.0	87.5	84.5
14	Glass Silicone (GS)	1/8	2	0.047	3	5.0	89.5	88.0	91.5	89.0
14	Glass Silicone (GS)	1/8	2	0.047	4	5.0	95.0	94.0	98.0	94.5
14	Glass Silicone (GS)	1/8	2	0.047	5	5.0	103.0	101.0	106.5	102.5
14	Glass Silicone (GS)	1/8	2	0.047	6	5.0	112.0	110.0	118.0	112.5
14	Glass Silicone (GS)	1/8	2	0.047	7	5.0	112.5	121.5	130.0	124.5
14	Glass Silicone (GS)	1/8	2	0.047	8	5.0	136.0	135.5	149.0	139.5
14	Glass Silicone (GS)	1/8	2	0.047	9	5.0	152.5	150.5	168.0	157.5
14	Glass Silicone (GS)	1/8	2	0.047	10	5.0	171.0	170.0	185.0	180.5

1 Test Pattern "C"

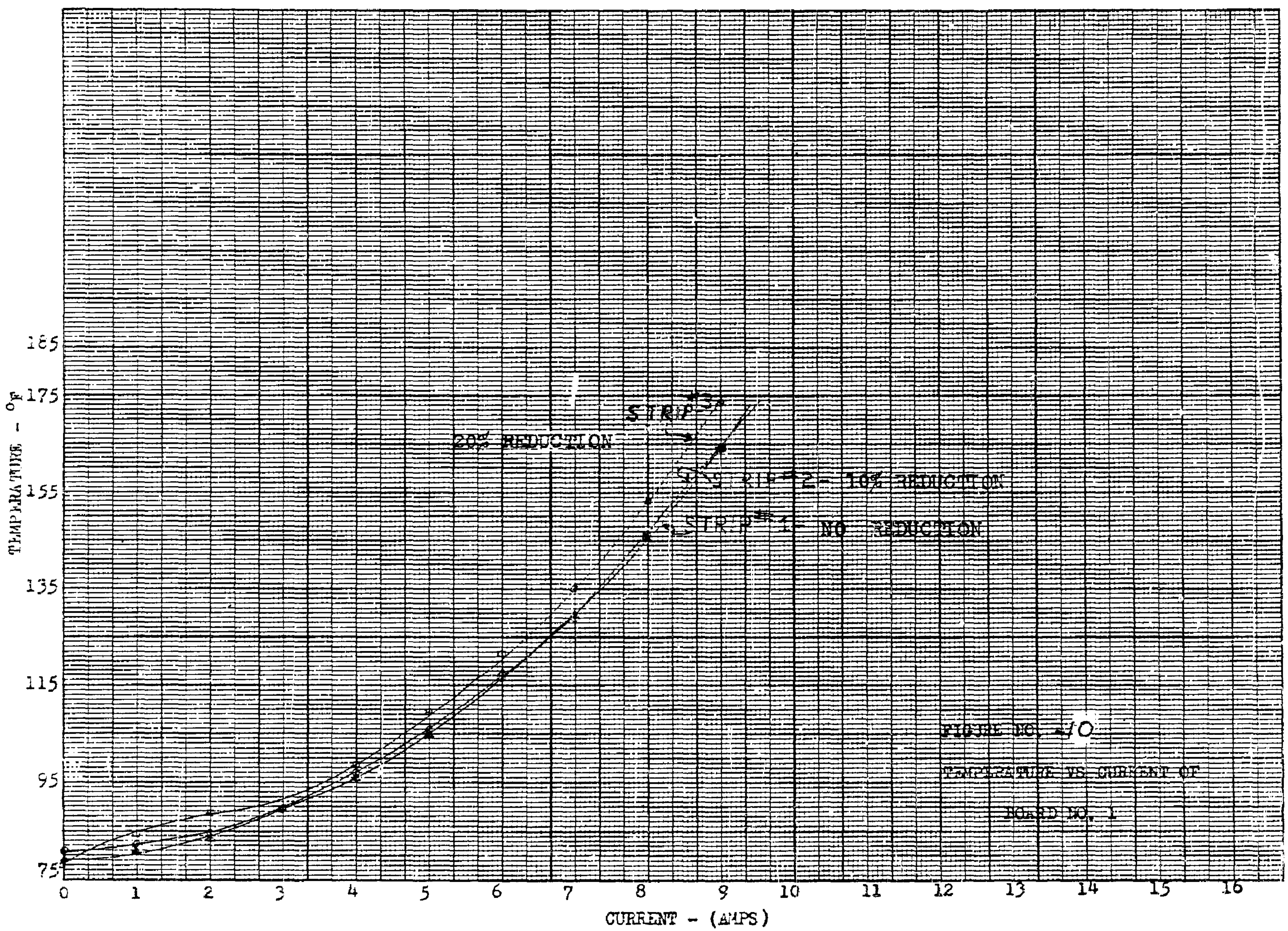


FIGURE NO. 10

TEMPERATURE VS CURRENT OF BOARD NO. 1

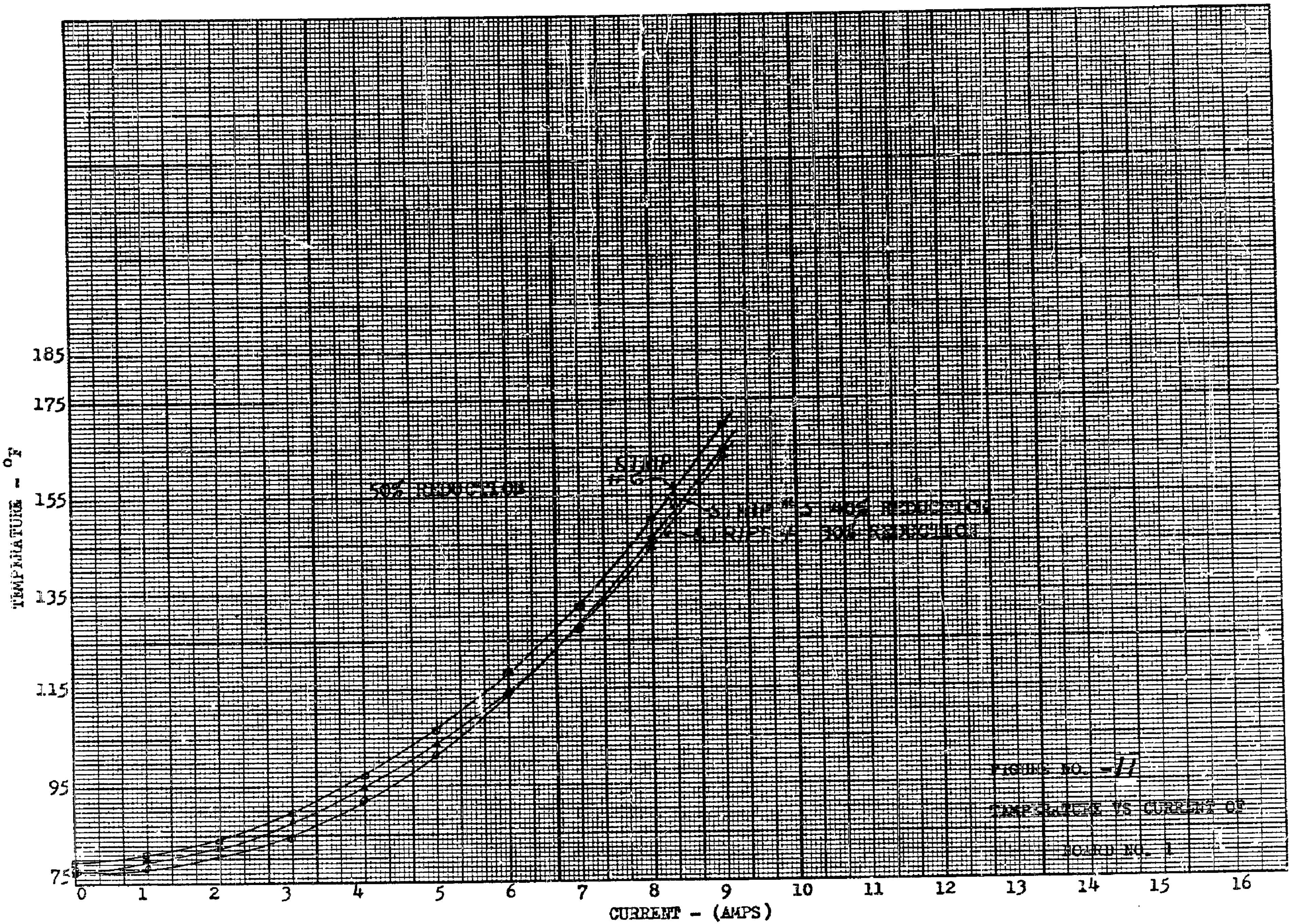
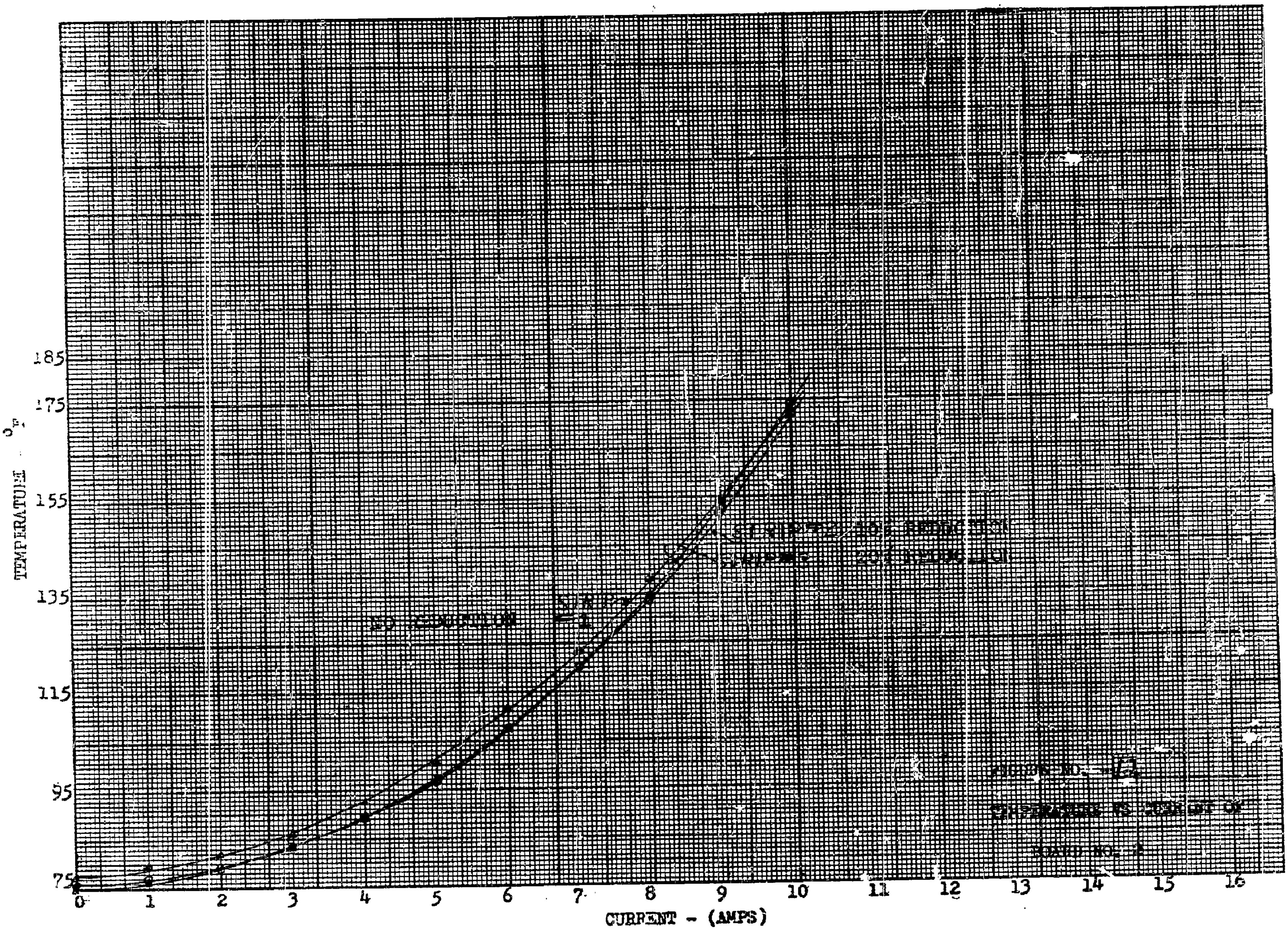


FIGURE NO. -17

TEMPERATURE VS CURRENT OF

BOARD NO. 1


TEMPERATURE °F
185
175
155
135
115
95
75
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
CURRENT - (AMPS)

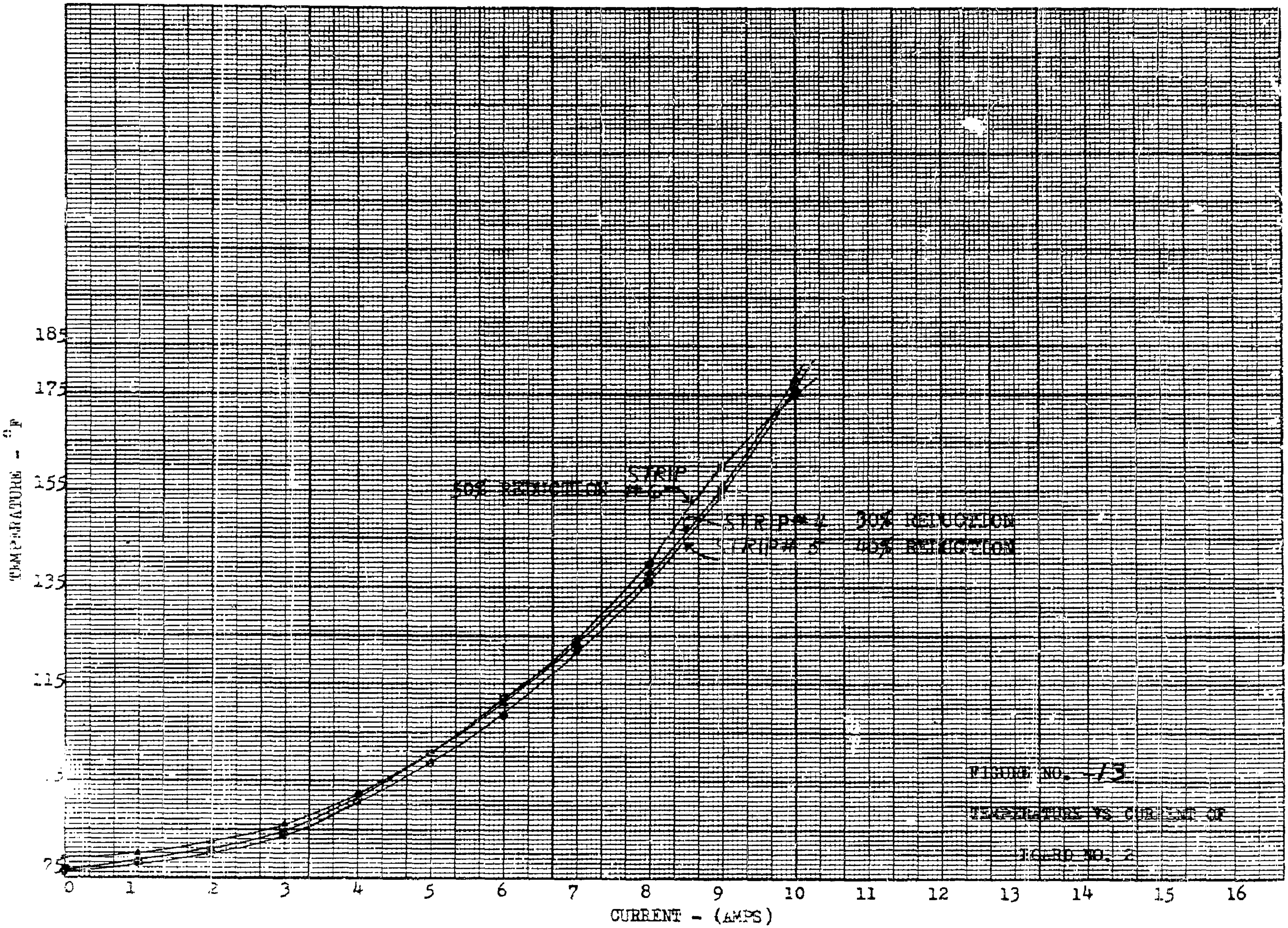
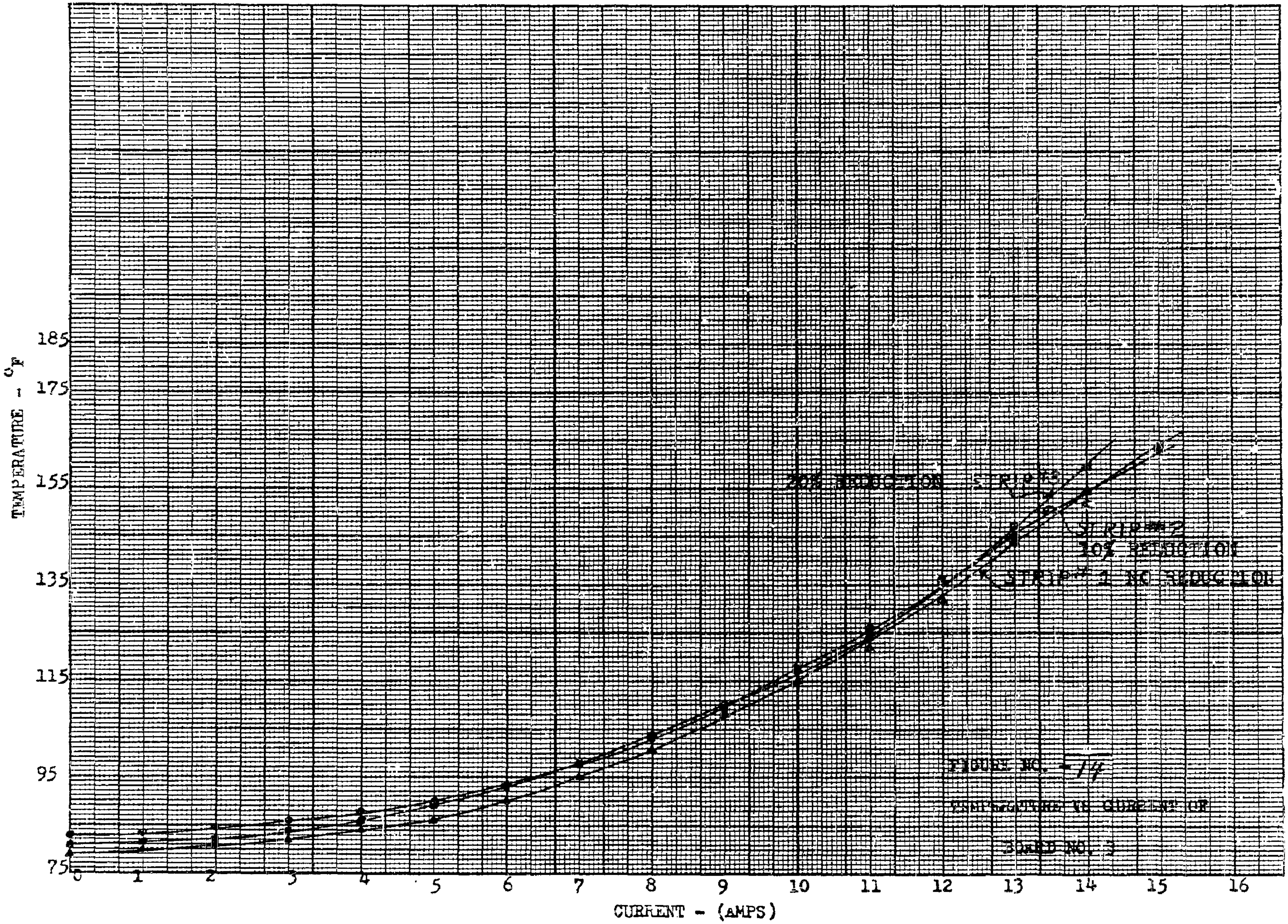
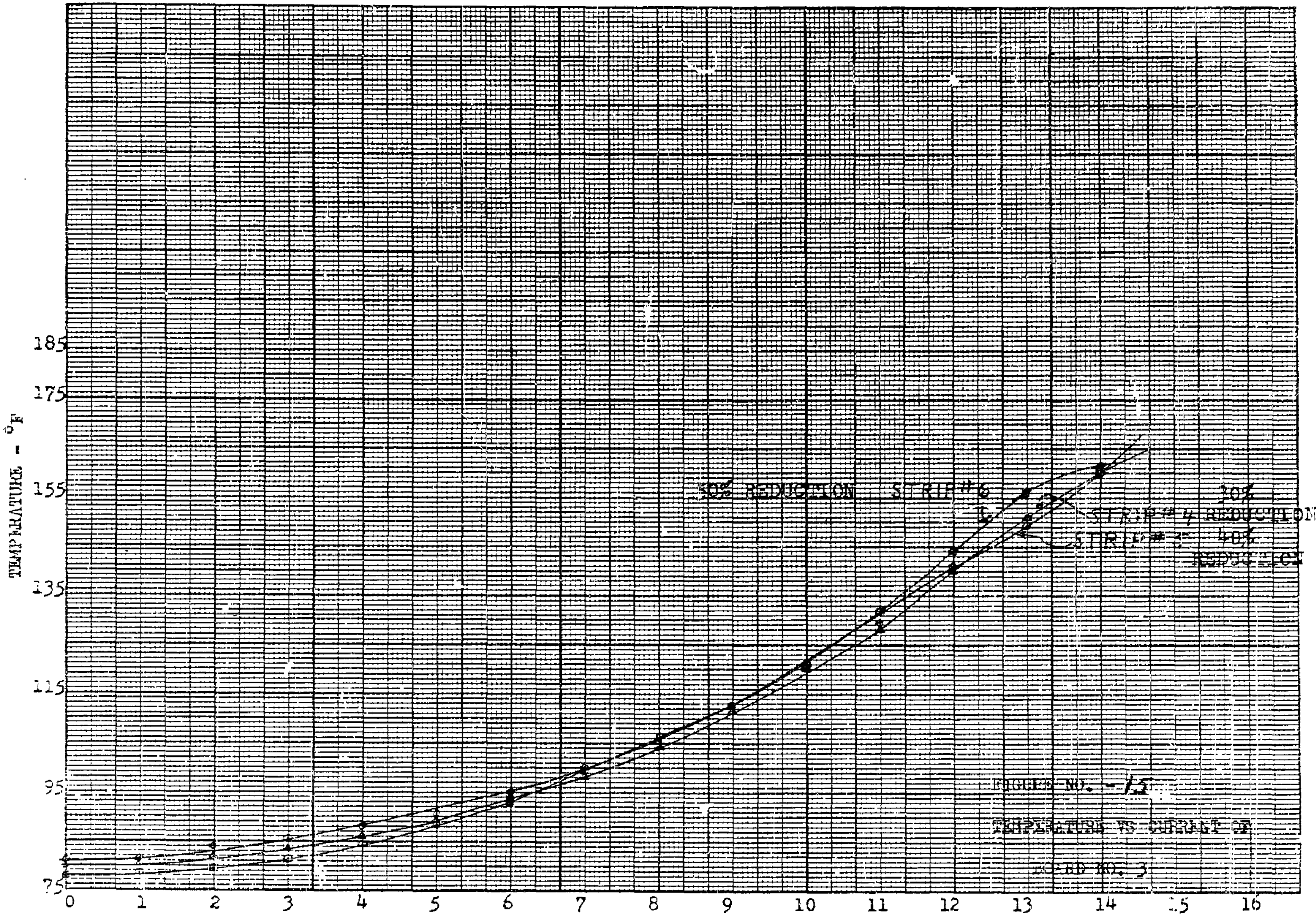


FIGURE NO. 13

TEMPERATURE VS CURRENT OF BOARD NO. 2



TEMPERATURE - °F
185
175
155
135
115
95
75
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
CURRENT - (AMPS)
20% REDUCTION STRIP #3
STRIP #2 10% REDUCTION
STRIP #1 NO REDUCTION
FIGURE NO. 14
TEMPERATURE VS CURRENT OF
BOARD NO. 3


TEMPERATURE - °F
185
175
155
135
115
95
75
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
CURRENT - (AMPS)
30% REDUCTION STRIP #6
STRIP #4 20% REDUCTION
STRIP #5 40% REDUCTION
FIGURE NO. - 15
TEMPERATURE VS CURRENT OF
BOARD NO. 3

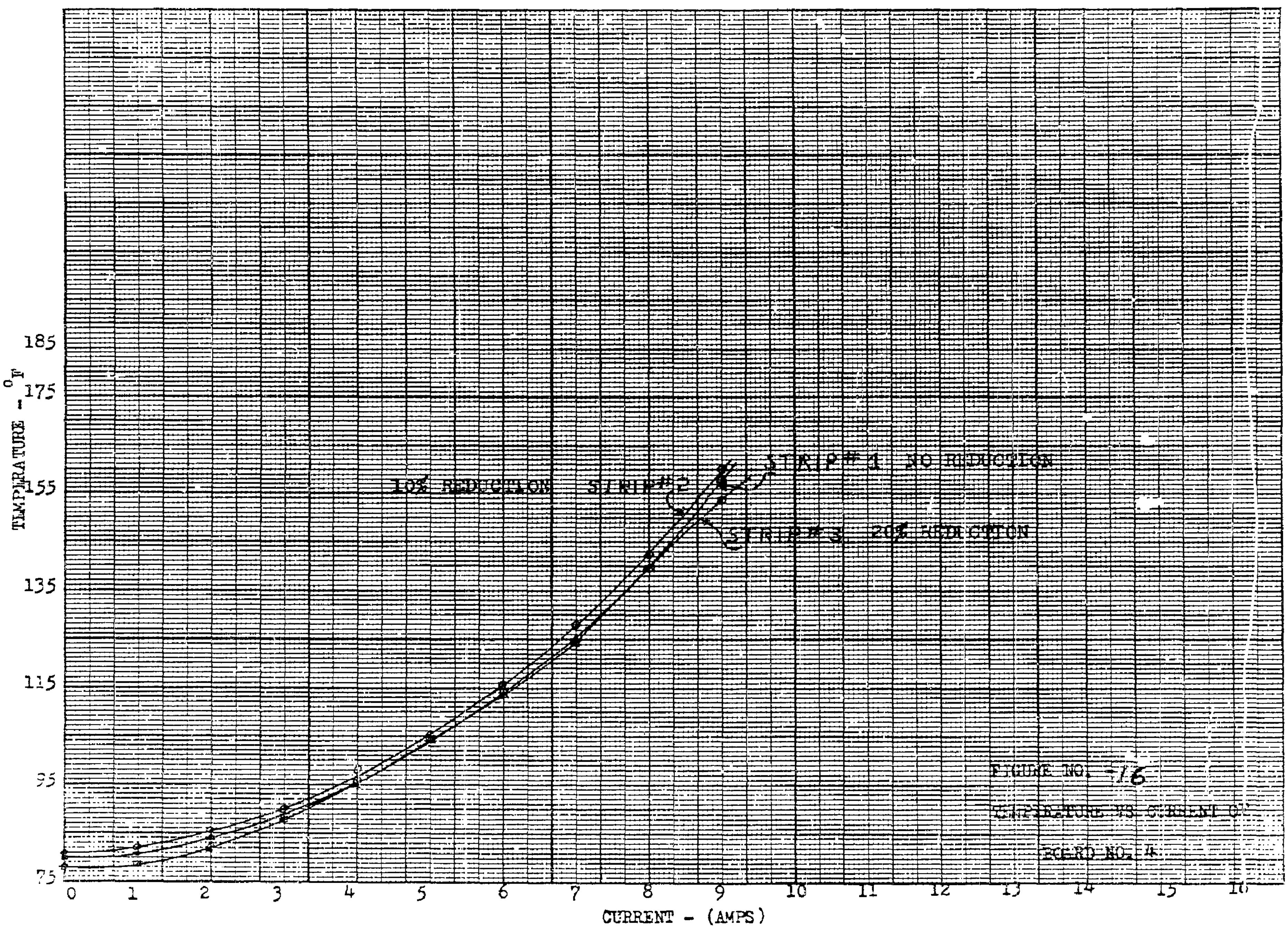


FIGURE NO. 16

TEMPERATURE VS CURRENT OF

BOARD NO. 4

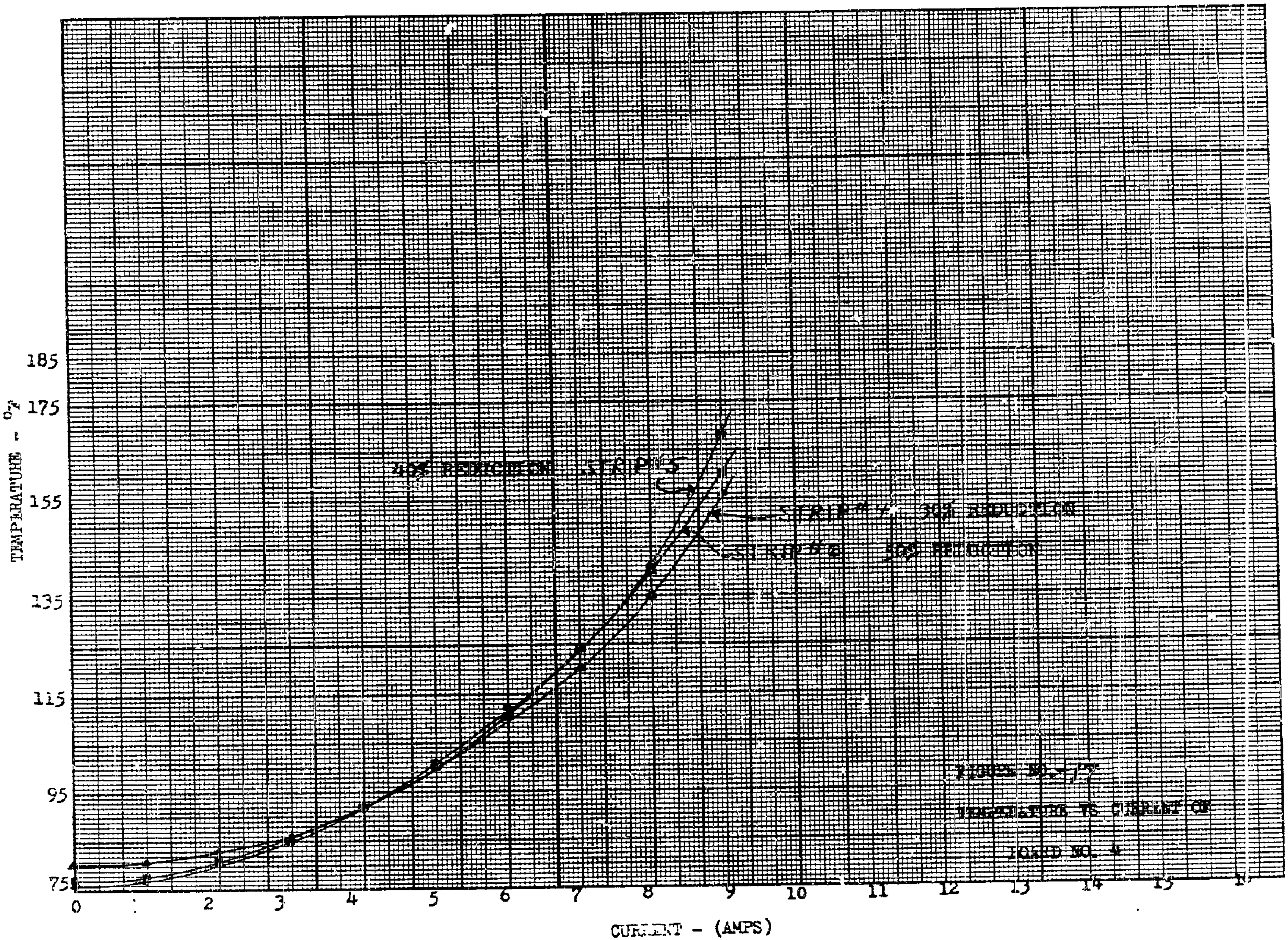
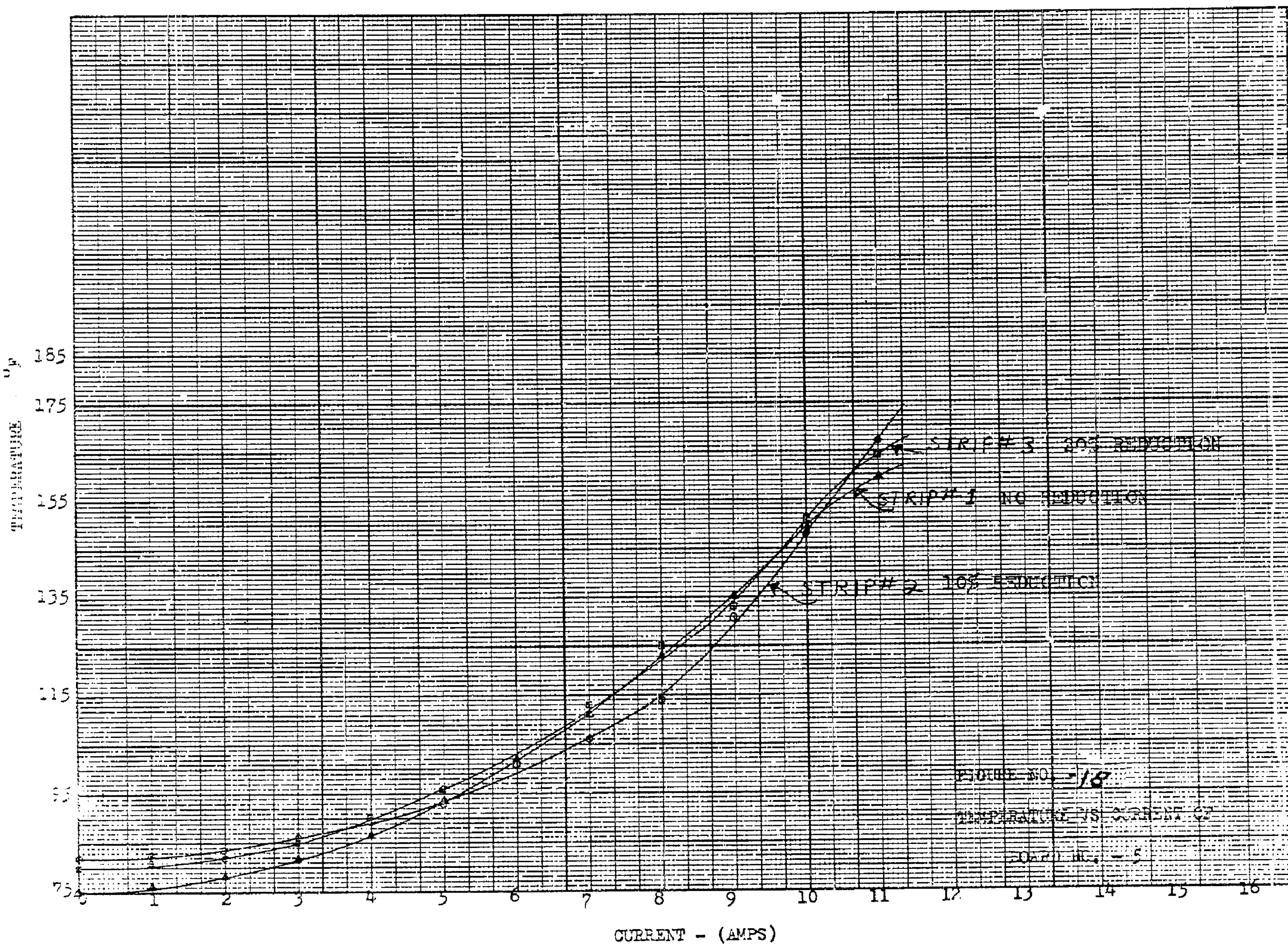


FIGURE NO. 17

TEMPERATURE VS CURRENT OF

BOARD NO. 4



°F
TEMPERATURE
185
175
155
135
115
95
75
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
CURRENT - (AMPS)
STRIP # 3 20% REDUCTION
STRIP # 1 NO REDUCTION
STRIP # 2 10% REDUCTION
FIGURE NO. -18
TEMPERATURE VS CURRENT OF
BOARD NO. - 5

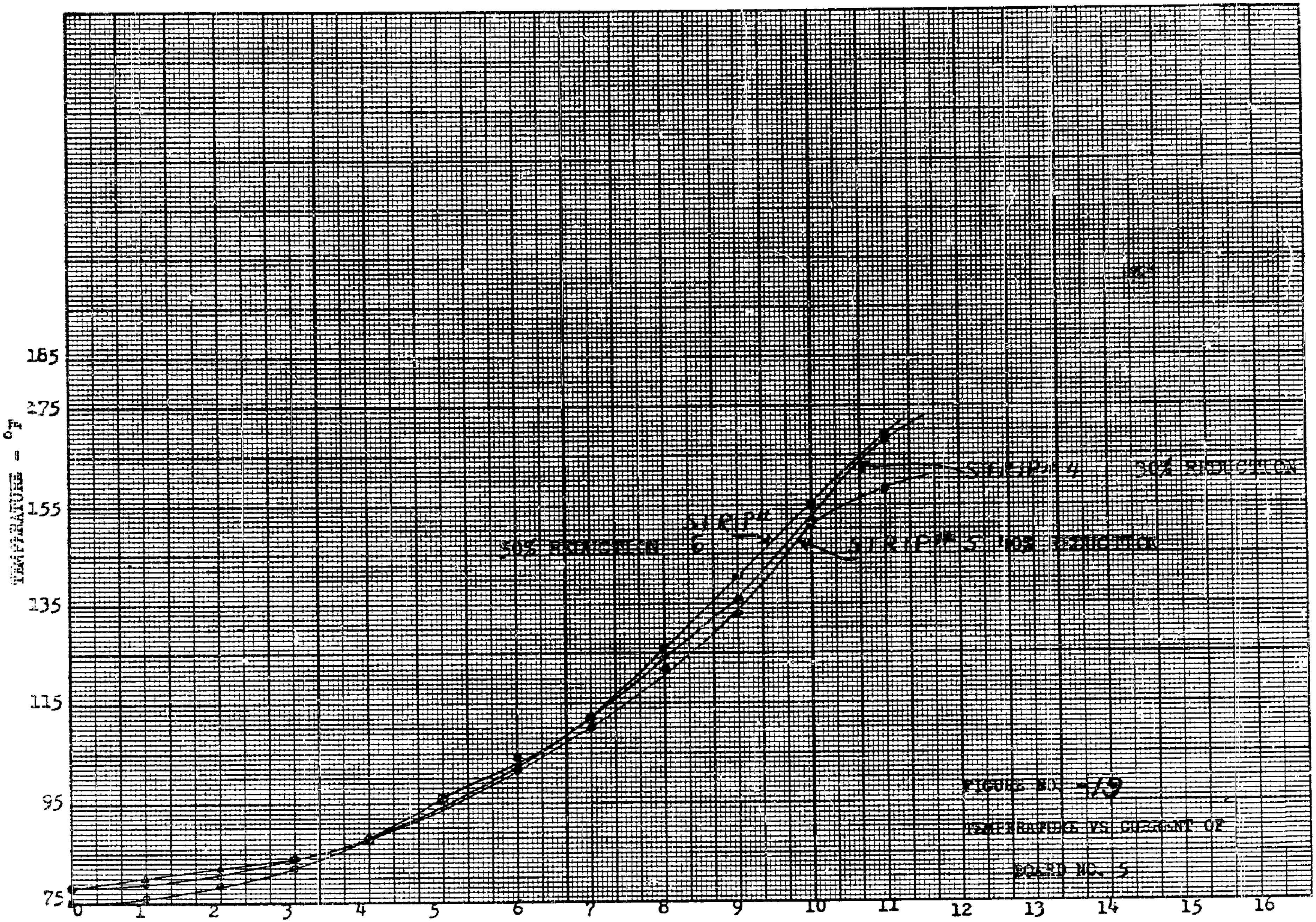


FIGURE NO. 19

TEMPERATURE VS. CURRENT OF

BOARD NO. 5

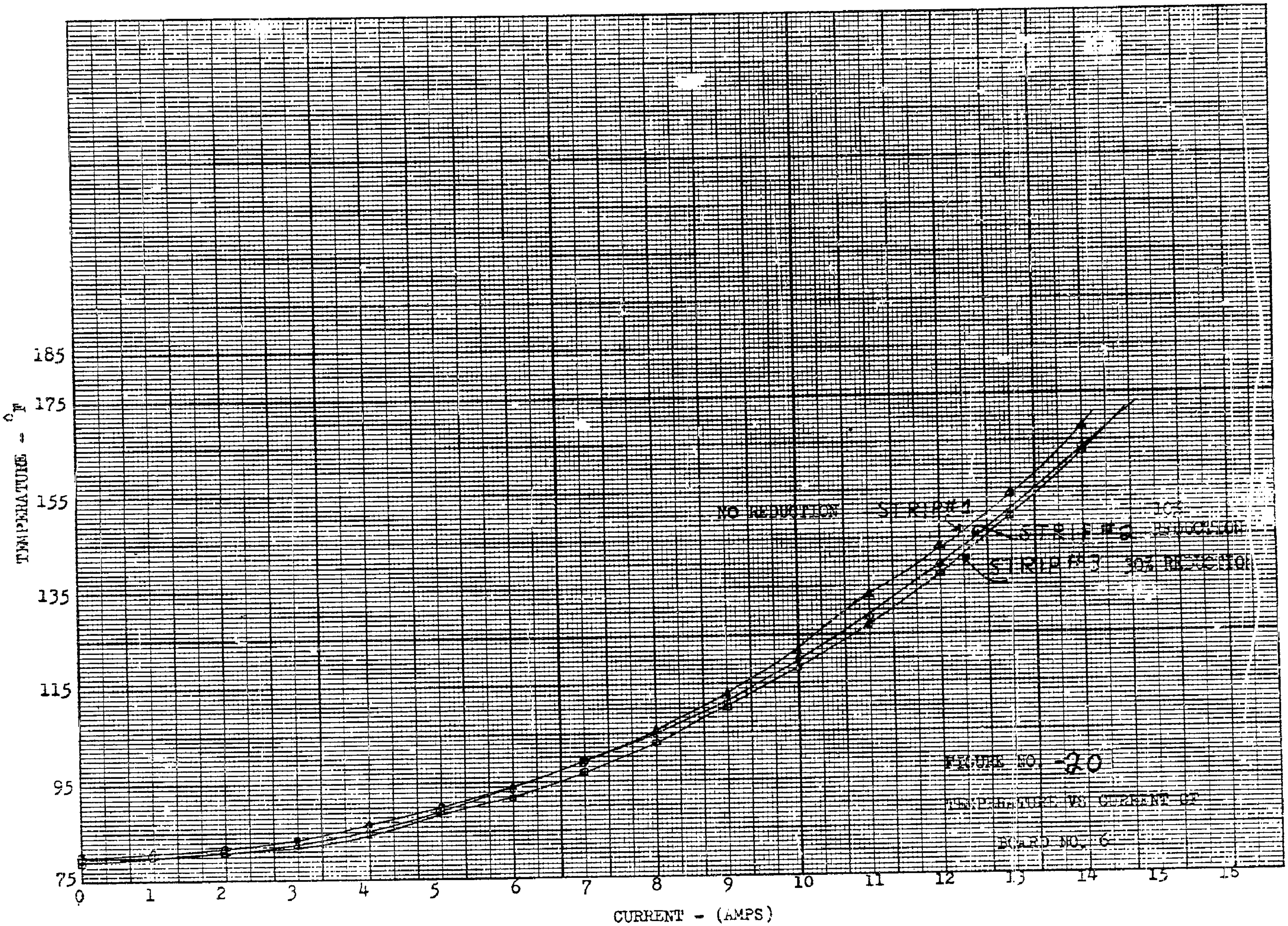


FIGURE NO. 20
TEMPERATURE VS CURRENT OF
BOARD NO. 6

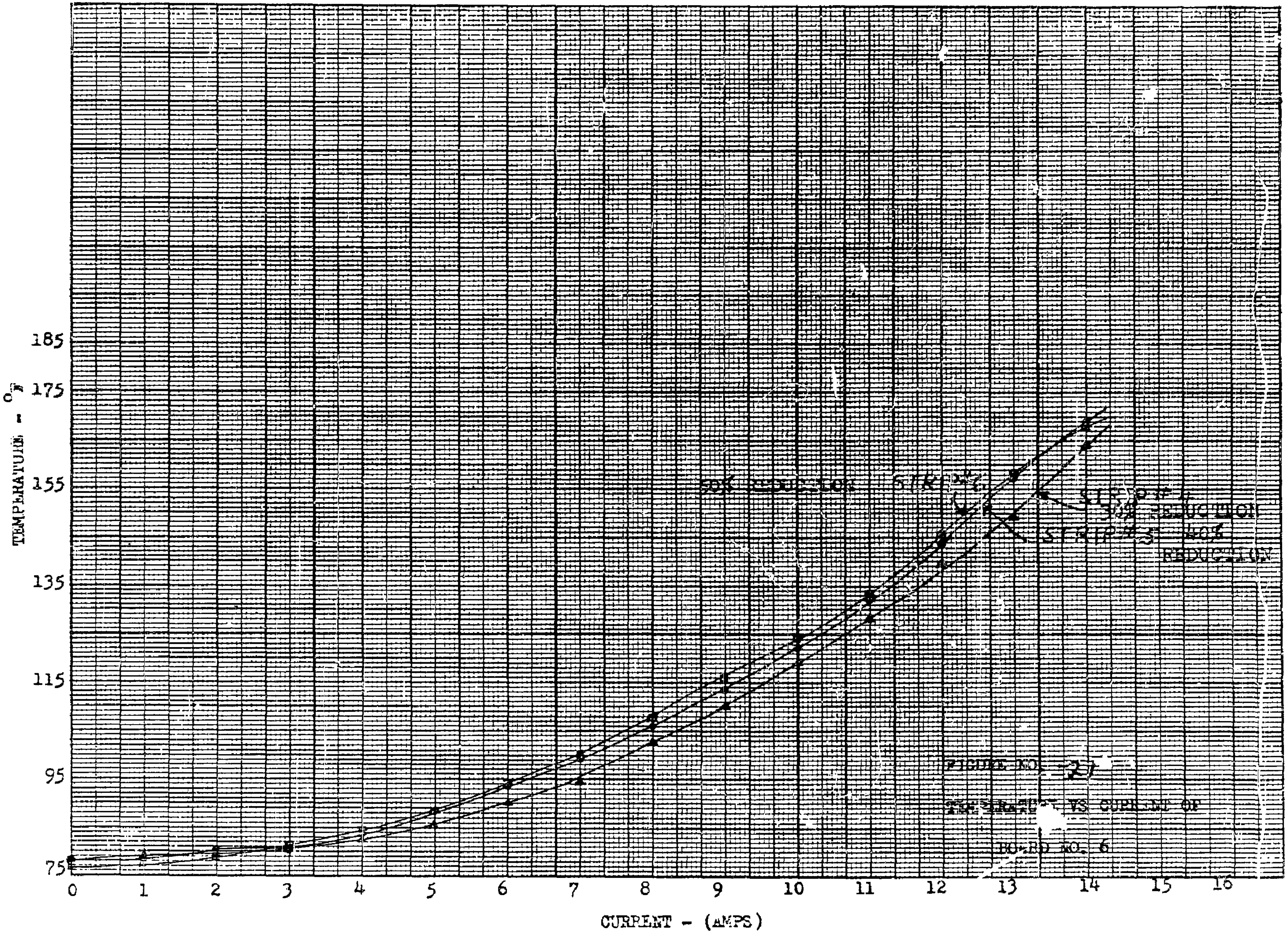


FIGURE NO. 27
TEMPERATURE VS CURRENT OF BOARD NO. 6

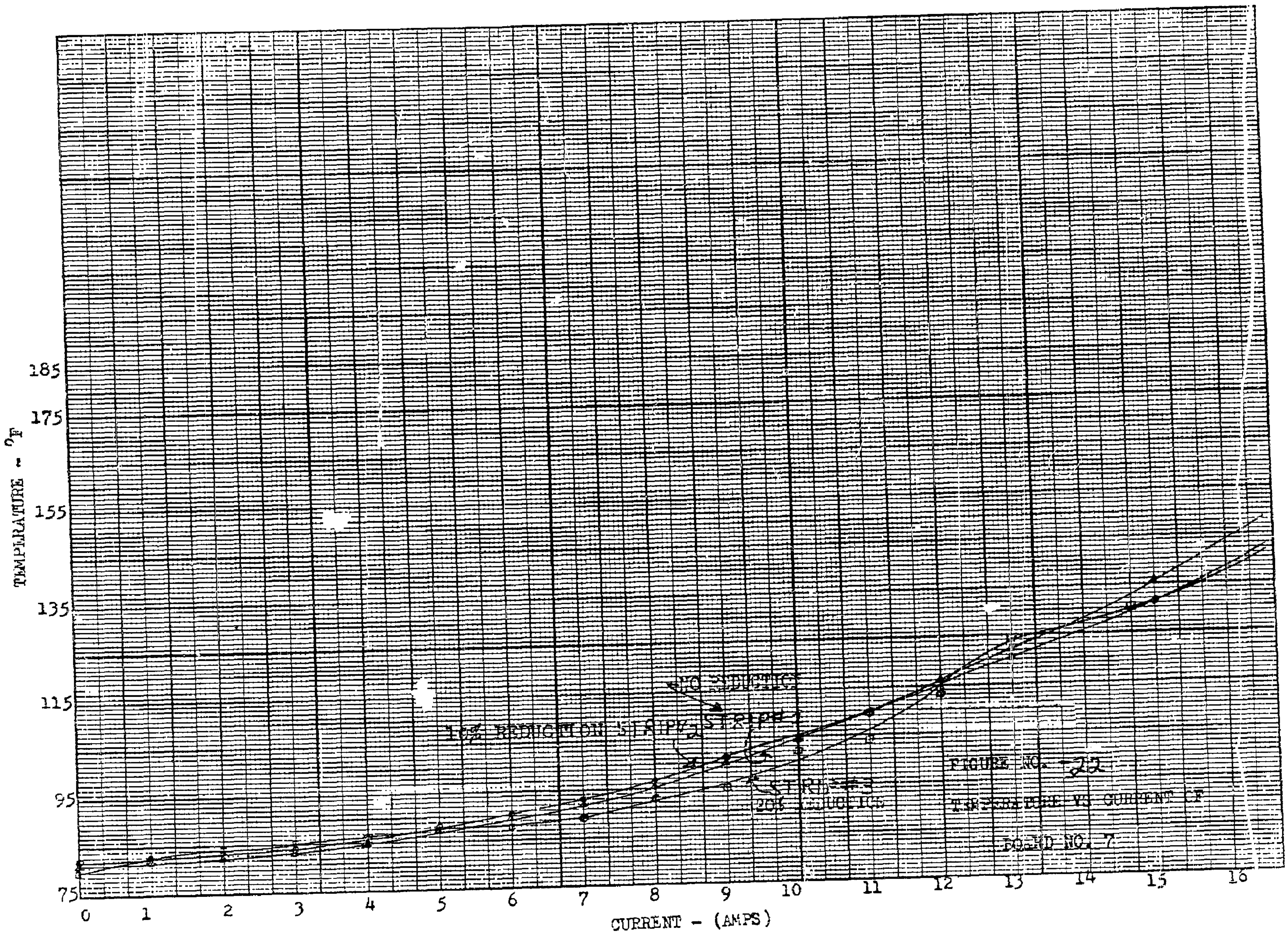


FIGURE NO. 22
TEMPERATURE VS CURRENT OF
BOARD NO. 7

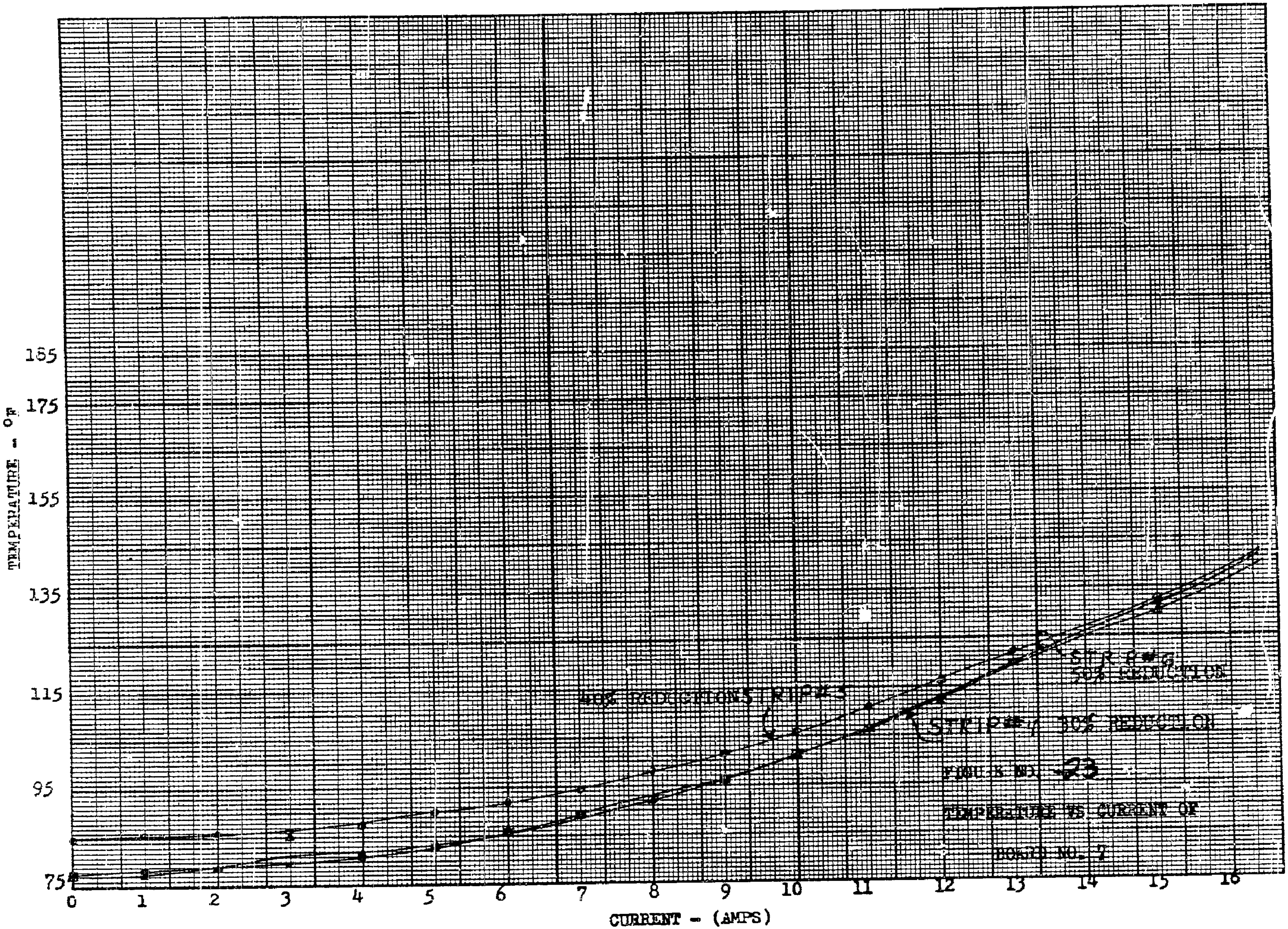


FIGURE NO. 23

TEMPERATURE VS CURRENT OF BOARD NO. 2

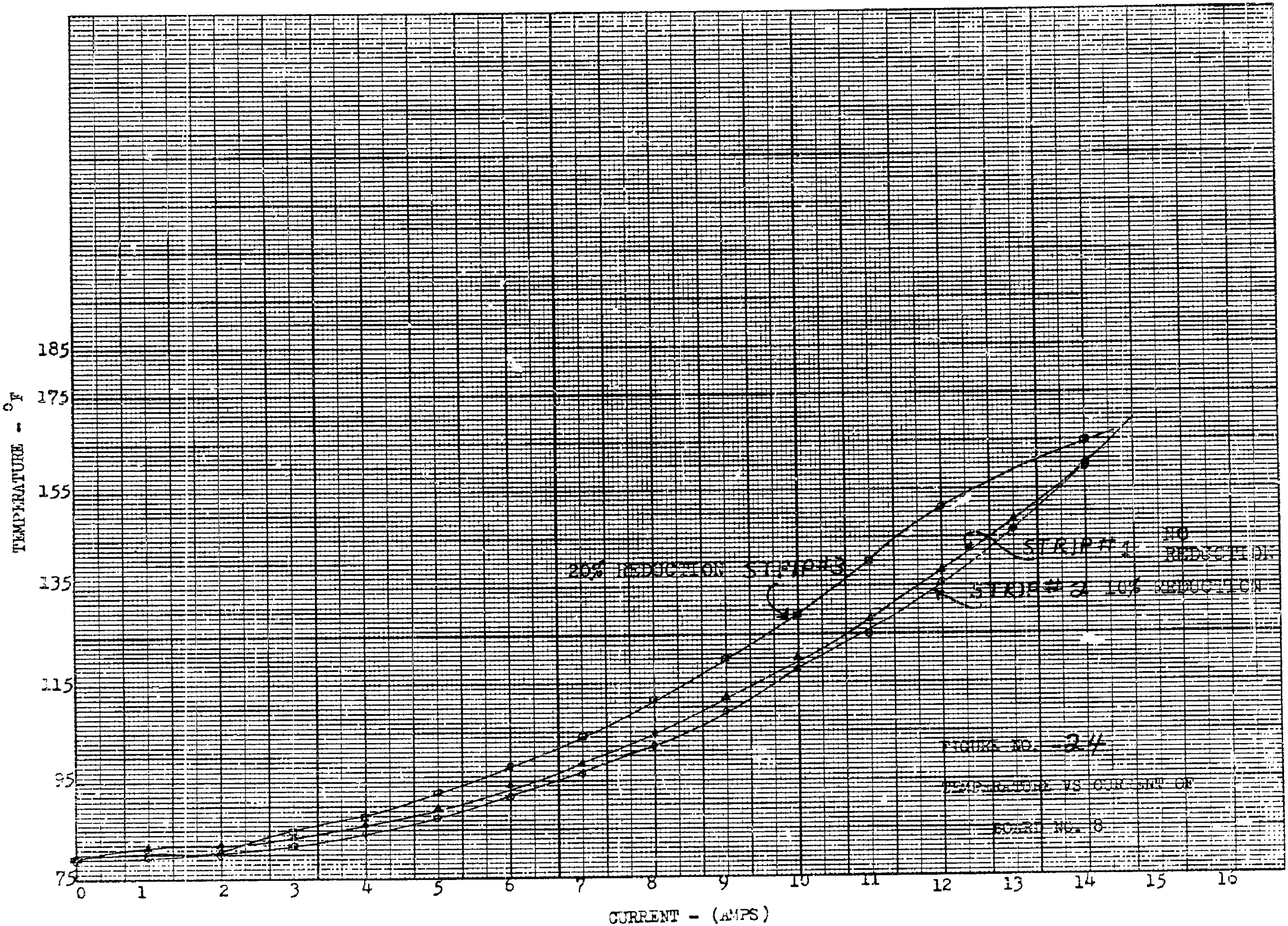


FIGURE NO. -24
TEMPERATURE VS CURRENT OF
BOARD NO. 8

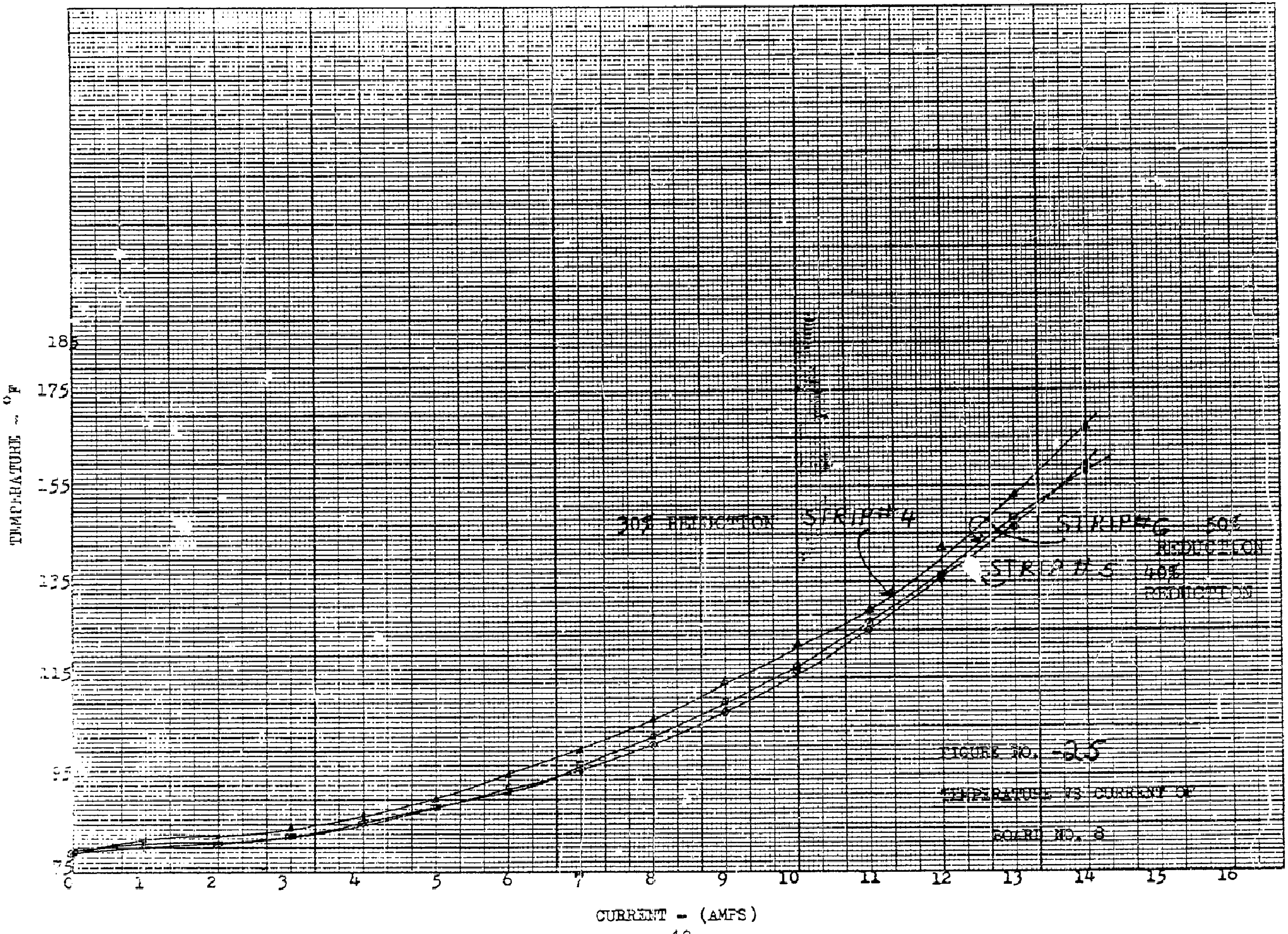


FIGURE NO. 25

TEMPERATURE VS CURRENT OF

BOARD NO. 8

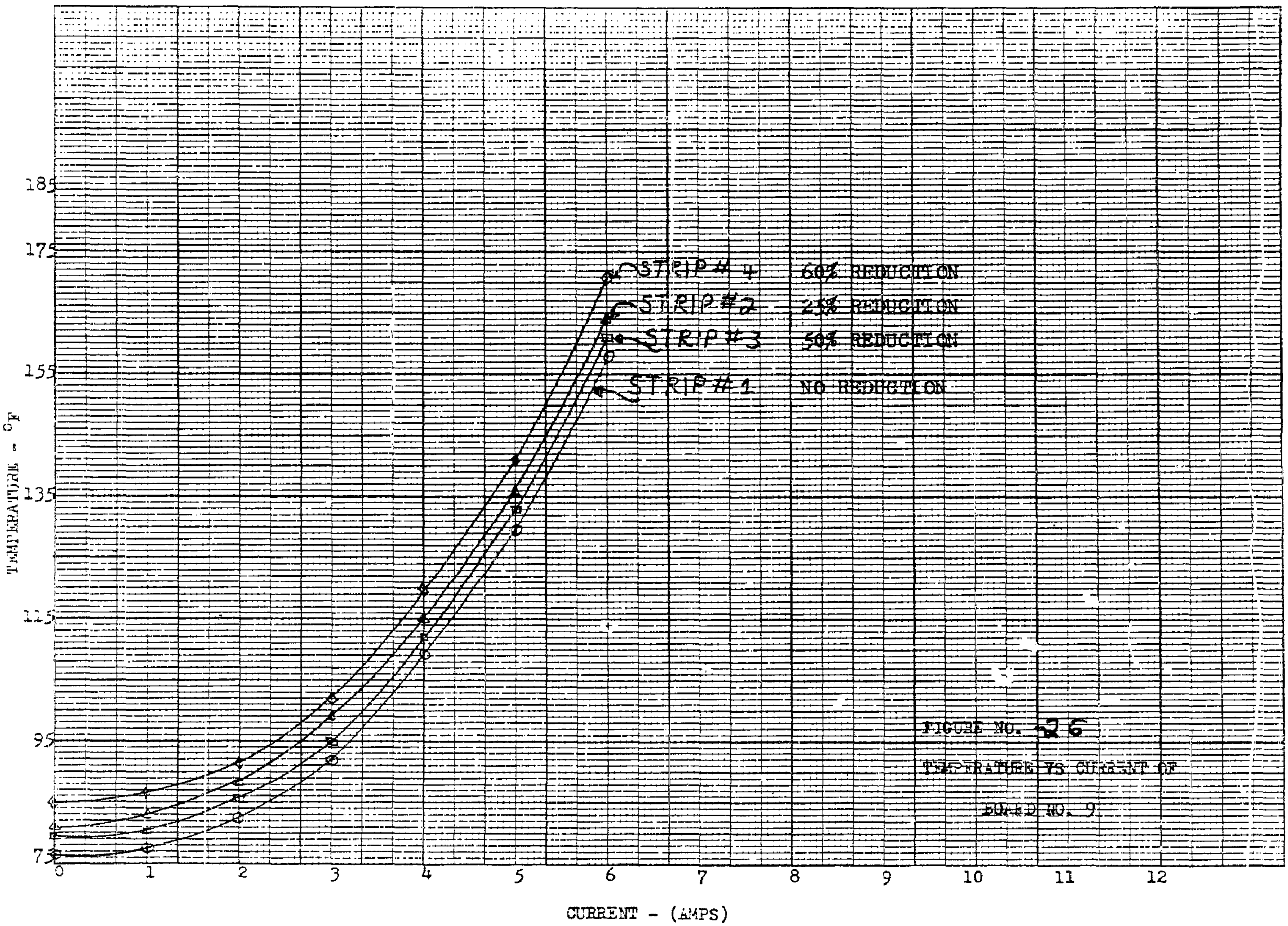
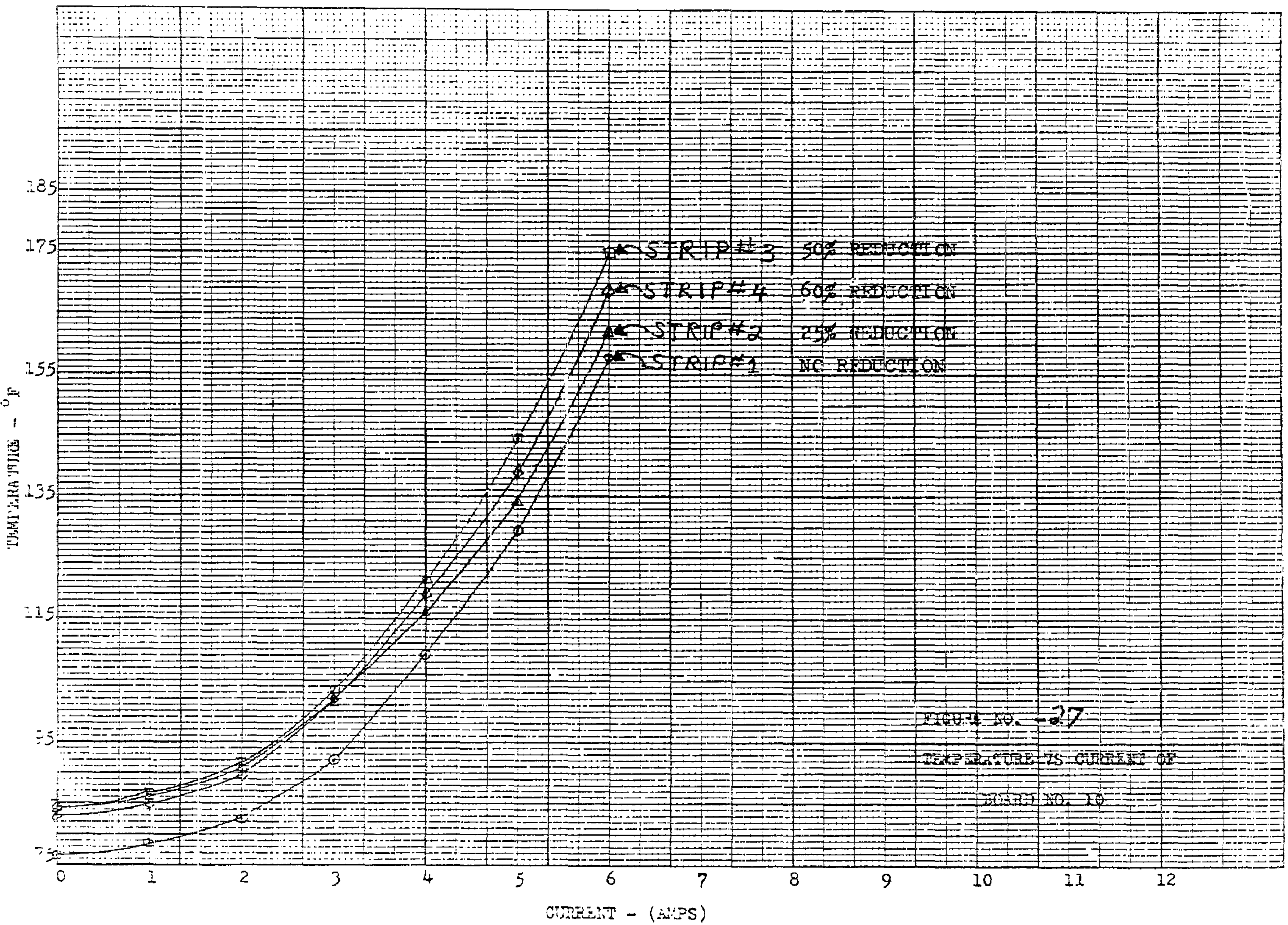
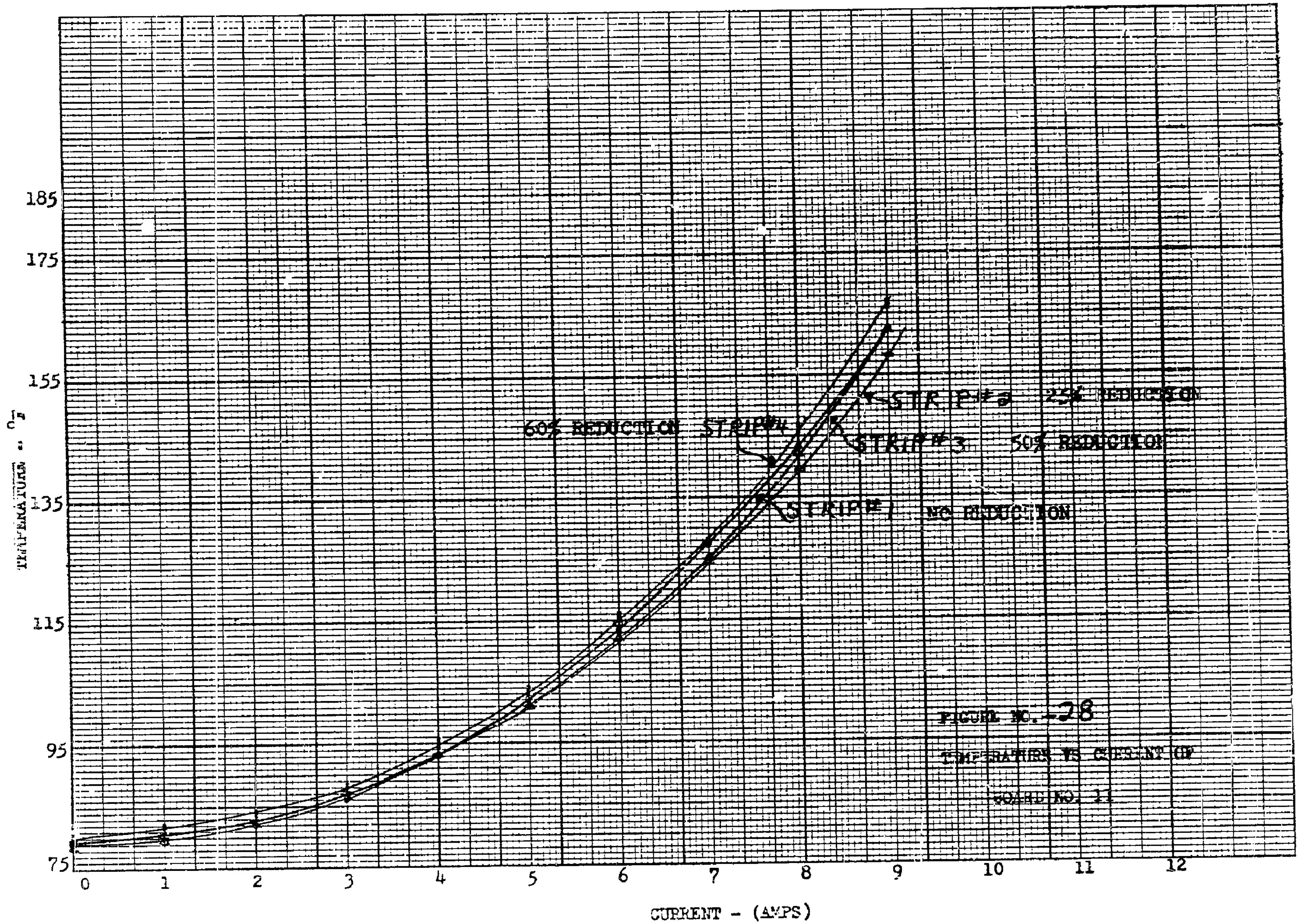


FIGURE NO. 26

TEMPERATURE VS CURRENT OF

BOARD NO. 9


185
175
155
135
115
95
75
TEMPERATURE - °F
0
1
2
3
4
5
6
7
8
9
10
11
12
CURRENT - (AMPS)
STRIP #3 50% REDUCTION
STRIP #4 60% REDUCTION
STRIP #2 25% REDUCTION
STRIP #1 NO REDUCTION
FIGURE NO. 27
TEMPERATURE VS CURRENT OF
BOARD NO. 10



185
175
155
135
115
95
75
TEMPERATURE - °F
0
1
2
3
4
5
6
7
8
9
10
11
12
CURRENT - (AMPS)
STRIP #2 25% REDUCTION
60% REDUCTION STRIP #4
STRIP #3 50% REDUCTION
STRIP #1 NO REDUCTION
FIGURE NO. -28
TEMPERATURE VS CURRENT OF
BOARD NO. 11

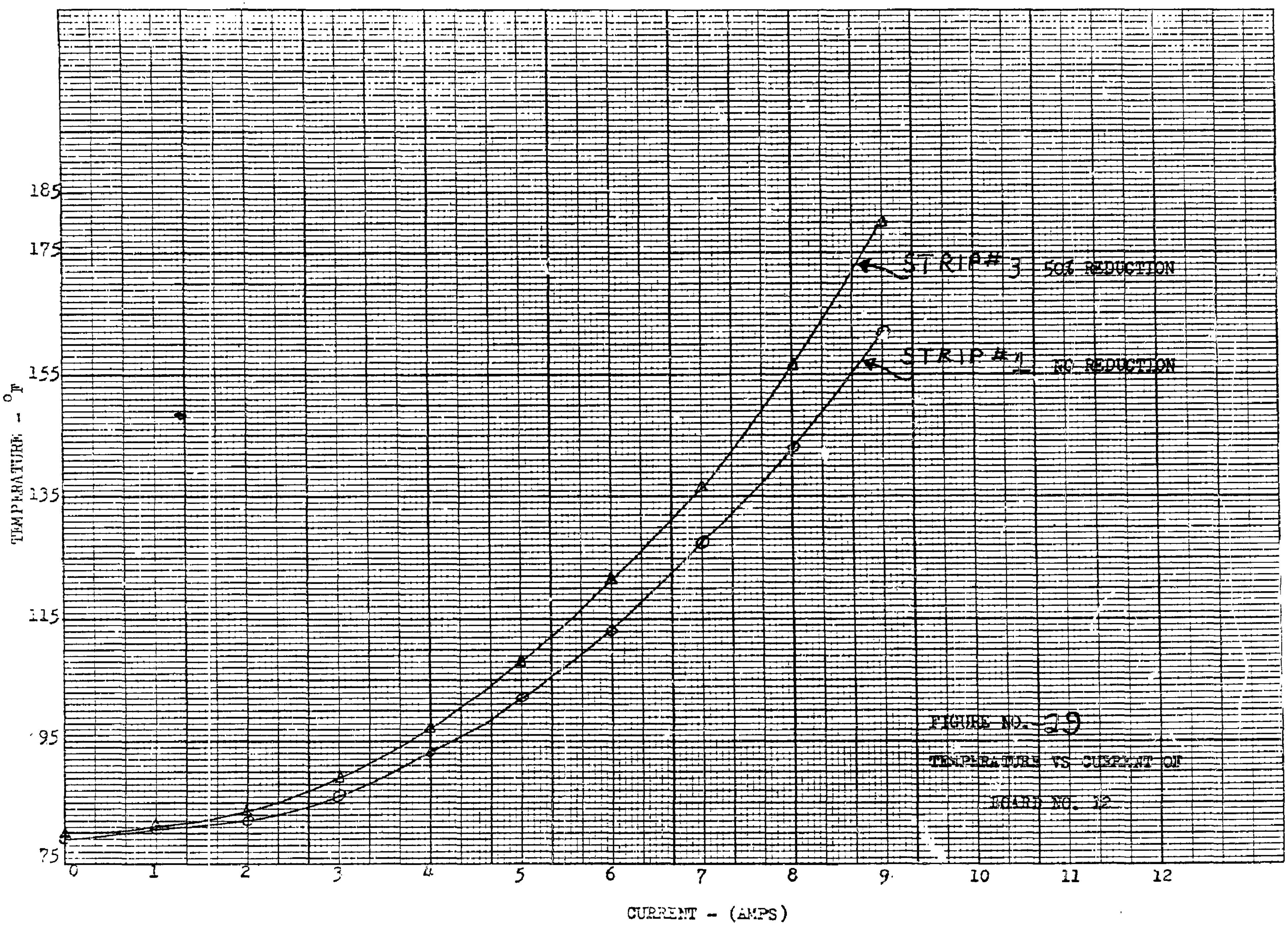


FIGURE NO. 29

TEMPERATURE VS CURRENT OF

BOARD NO. 12

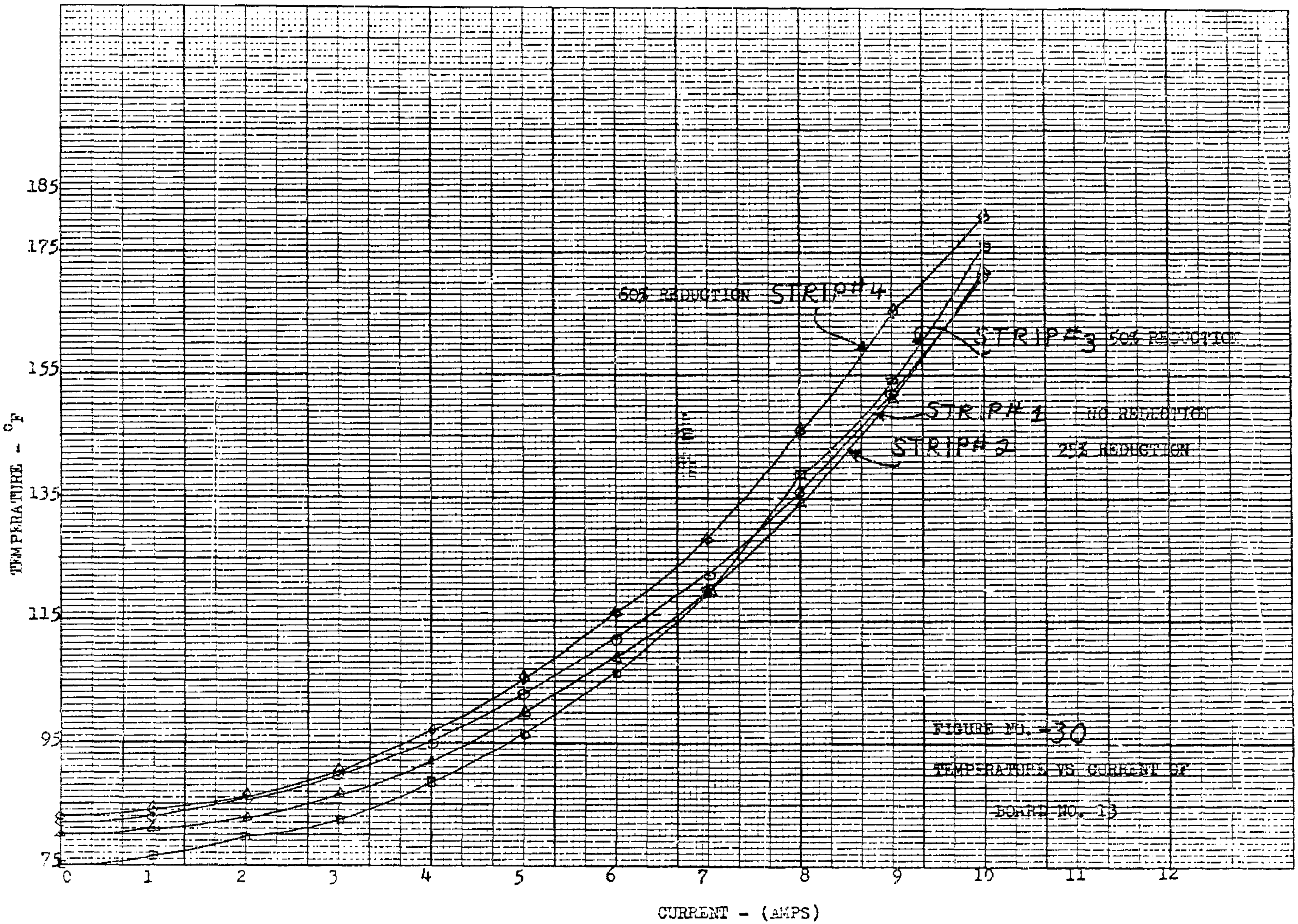


FIGURE NO. 30

TEMPERATURE VS CURRENT OF BOARD NO. 13

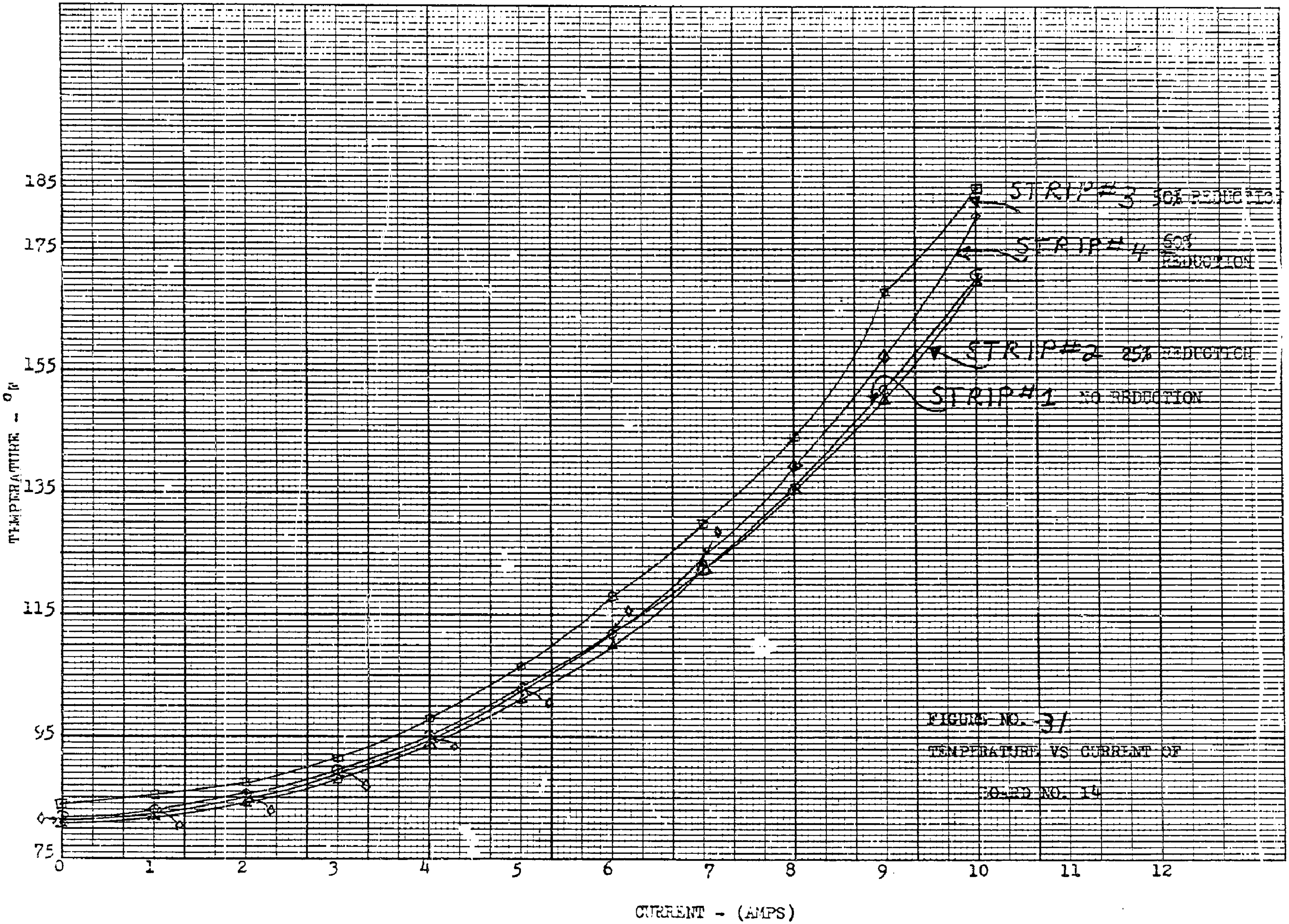


FIGURE NO. 31
TEMPERATURE VS CURRENT OF
BOARD NO. 14

Test Board No.	Base Laminate		Laminate Thickness	Approx. Weight	Test Pattern
7	Glass Epoxy	(GE)	1/8 in.	2 oz.	A
8	Glass Silicone	(GS)	1/8 in.	2 oz.	A
9	Paper Epoxy	(PX)	1/8 in.	1 oz.	B
10	Paper Epoxy	(PX)	1/8 in.	1 oz.	C
11	Paper Epoxy	(PX)	1/8 in.	2 oz.	B
12	Paper Epoxy	(PX)	1/8 in.	2 oz.	C
13	Glass Silicone	(GS)	1/8 in.	2 oz.	B
14	Glass Silicone	(GS)	1/8 in.	2 oz.	C

The Paper Phenolic and Paper Epoxy base laminate board material showed no difference in the effect of temperature rise on the copper conductor. Test boards 1 to 8 using Pattern "A" (Figure No. 1) showed that a variation in the conductor line width of ~~0.50~~ to 0.100 inch at the notch had very little effect on temperature rise in the conductor. 0.05

A smaller conductor line width was made (See Pattern "B", Figure No. 2) in order to see if there would be any further temperature difference as a result of reducing the line width of a copper conductor from ~~0.47~~ to 0.020 inches. See boards 9, 11 and 13 for test data. 0.047

Pattern "C" (See Figure No. 3) was made to evaluate the effect of multiple notched areas in a copper conductor. Test boards 10, 12 and 14 test results showed that multiple notched areas had no effect on temperature rise.

Peel strength measurements were made on conductors which had been measured for temperature rise. To compare the peel strength data of the tested boards, peel strength tests were performed on test boards not tested for temperature rise values. Table XV shows the peel strength data on boards 1 to 8 not tested for temperature rise values. Table XVI shows the peel strength values on test boards 1 to 9 respectively and boards 11 and 13 subjected to temperature versus current measurements.

Comparing both tables with respect to peel strength test results, the following results were:

Material	Increased Peel Strength After Test (lbs/inch width)
1 oz. - Paper Phenolic (XXXP)	0.60 lbs.
2 oz. - Paper Phenolic (XXXP)	1.00 lbs.
1 oz. - Paper Epoxy (PX)	No change
2 oz. - Paper Epoxy (PX)	No change

TABLE XV

PEEL STRENGTH TEST RESULTS ON UNTESTED BOARDS

Test Board No.	Type of Base Laminate	Laminate Thickness (Inch)	Copper Foil Weight (OZ)	Conductor Line Width (Inch)	Peel Strength For Notch Sized Conductors (LBS.)					
					None	10%	20%	30%	40%	50%
1	Paper Phenolic (XXXP)	1/16	1	0.100	10.0	10.0	10.0	10.62	10.0	10.0
2	Paper Phenolic (XXXP)	1/8	1	0.100	10.0	10.0	10.0	10.0	10.62	10.0
3	Paper Phenolic (XXXP)	1/8	2	0.100	10.62	10.62	11.25	11.25	11.25	11.25
4	Paper Epoxy (FX)	1/16	1	0.100	11.87	11.25	10.62	10.62	10.62	10.0
5	Paper Epoxy (FX)	1/8	1	0.100	12.5	13.12	13.75	13.75	13.75	12.5
6	Paper Epoxy (FX)	1/8	2	0.100	18.12	18.12	18.75	18.12	18.75	18.75
7	Glass Epoxy (GE)	1/8	2	0.100	18.12	18.12	18.12	18.12	18.75	19.38
8	Glass Silicone (GS)	1/8	2	0.100	10.0	9.38	9.38	9.38	9.38	8.75

TABLE XVI

PEEL STRENGTH TEST RESULTS ON TESTED BOARDS

Test Board No.	Type of Base Laminate	Laminate Thickness (Inch)	Copper Foil Weight (OZ)	Conductor Line Width (Inch)	Peel Strength For Notch Sized Conductors (LBS.)					
					None	10%	20%	30%	40%	50%
1	Paper Phenolic (XXXP)	1/16	1	0.100	11.25	10.6	10.6	10.6	10.6	10.6
2	Paper Phenolic (XXXP)	1/8	1	0.100	10.6	10.0	10.0	10.6	10.6	10.6
3	Paper Phenolic (XXXP)	1/8	2	0.100	11.25	11.9	11.9	11.9	11.9	12.5
4	Paper Epoxy (PX)	1/16	1	0.100	10.6	10.6	11.25	10.6	11.25	10.6
5	Paper Epoxy (PX)	1/8	1	0.100	12.5	13.1	13.1	13.7	13.7	13.7
6	Paper Epoxy (PX)	1/8	2	0.100	18.75	18.75	18.75	18.75	18.75	18.12
7	Glass Epoxy (GE)	1/8	2	0.100	18.1	18.1	19.4	20.0	20.0	20.0
8	Glass Silicone (GS)	1/8	2	0.100	11.9	11.9	11.9	11.25	11.25	10.6
					None	25%		50%		60%
9	Paper Epoxy (PX)	1/8	1	0.047	12.0	12.0		10.6		12.0
11	Paper Epoxy (PX)	1/8	2	0.047	19.9	19.9		19.9		19.9
13	Glass Silicone (GS)	1/8	2	0.047	13.3	13.3		13.3		13.3

Material	Increased Peel Strength After Test (lbs/inch width)
2 oz. - Glass Epoxy (GE)	1.00 lbs.
2 oz. - Glass Silicone (GS)	2.00 lbs.

The slight increase in peel strength of those boards subjected to heat produced from the current was probably caused by some additional curing of the bonding resin.

Figure No. 32 shows various conductor line width on production type circuit boards. Line widths shown in Figure No. 1 vary from ~~0.100 to 0.0500~~ of an inch.
0.020 TO 0.100

In order to establish the temperature at which a copper conductor would separate from the base laminate, several tests were performed on 1 and 2 oz. copper test specimens. The test results are as follows:

Laminate Type		Copper Weight	Conductor Width at Notch	Current (Amperes)	Temperature (^{O}F)
Paper Epoxy	(PX)	1 oz.	0.020 Inch	9.0	350
Paper Epoxy	(PX)	2 oz.	0.035 Inch	9.0	350
Paper Epoxy	(PX)	2 oz.	0.035 Inch	13.5	375
Glass Silicone	(GS)	2 oz.	0.035 Inch	15.0	350
Glass Silicone	(GS)	2 oz.	0.047 Inch	17.5	475-500

All five tests were performed on 1/8 inch thick material and the pattern used was "C". The point at which the temperature was read was at the point of destruction. The point of destruction being defined as the point at which there is a visible sign of separation of the copper conductor from the base material.

Results on test boards 15 through 21 are reported in tables XVII through XXIII. These test board patterns differed from test boards 1 through 14 in that nicks, pin holes, and scratches were deliberately inscribed at random on production boards to obtain closer data on actual production parts. The board number, type of base laminate, copper weight, and temperatures at which copper discolored are given below:

Board No.	Base Laminate		Copper Weight	Temperature at which Copper Discolored
15	Paper Phenolic	(PP)	1 oz.	210^{O}F
16	Paper Phenolic	(PP)	2 oz.	200^{O}F
17	Paper Epoxy	(PX)	2 oz.	192-200^{O}F
18	Glass Epoxy	(GE)	1 oz.	206-238^{O}F

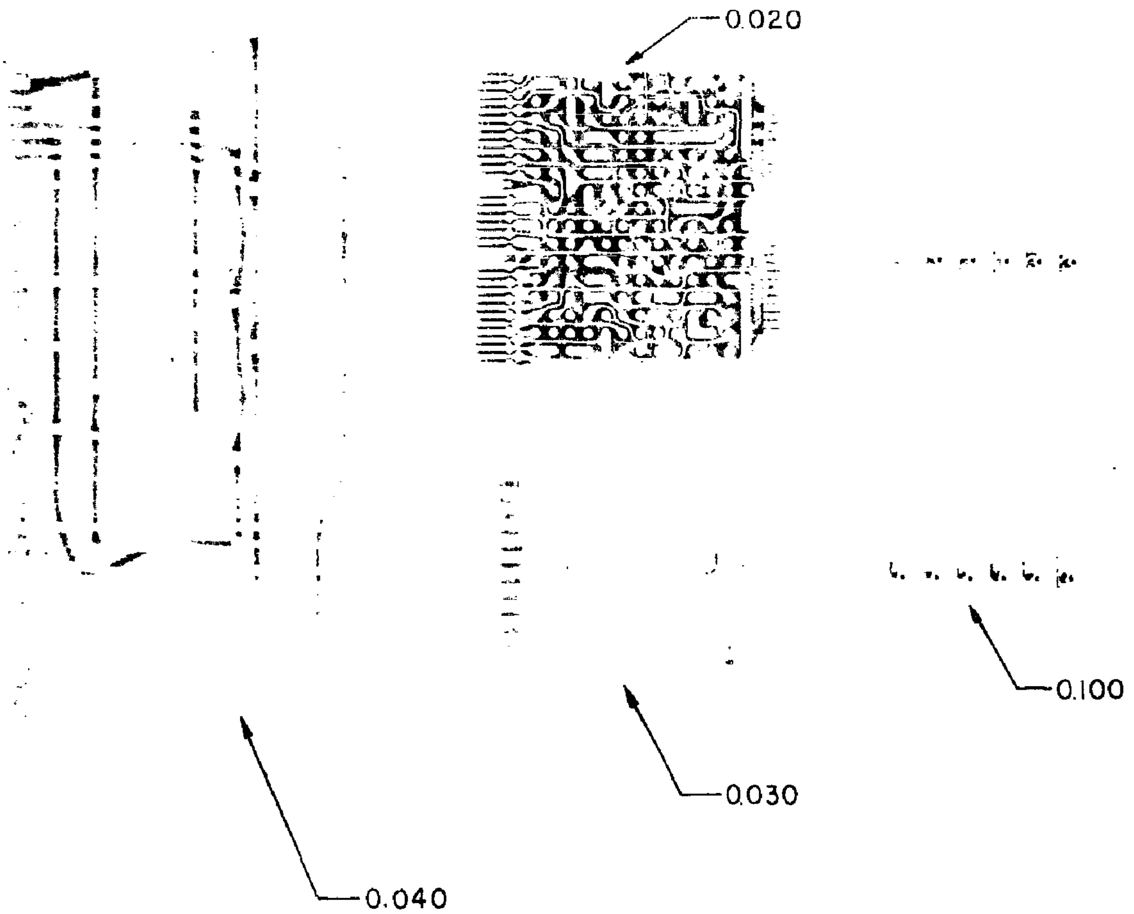


Figure No. 32. Various Conductor Line Widths on Production Type Circuit Boards

TABLE XVII

TEMPERATURE RISE VS CURRENT ON PAPER PHENOLIC (1/8 INCH THICKNESS - 1 OZ.) COPPER

Board No.	Board Type & Thickness (Inch)	Copper Weight (Oz.)	Reduction of Copper Conductor at Point of Measurement-(Inches) *(Due to Condition No.)	Time In (Min.)	Ampere I (Amps.)	Temperature (C°)	Temperature Rise In °C (Above Ambient - 25°C)
15	PP-1/8	1	0.031 - Condition 1	0	0	0	0
15	PP-1/8	1	0.031 - Condition 1	4	1	30	5
15	PP-1/8	1	0.031 - Condition 1	4	5	33	8
15	PP-1/8	1	0.031 - Condition 1	3	6	52	27
15	PP-1/8	1	0.031 - Condition 1	3	7	64	39
15	PP-1/8	1	0.031 - Condition 1	3	8	83	58
15	PP-1/8	1	0.031 - Condition 1	3	[1] 9	110	85
15	PP-1/8	1	0.031 - Condition 1	1	10	122	97
15	PP-1/8	1	0.022 - Condition 2	4	1	26	1
15	PP-1/8	1	0.022 - Condition 2	4	5	38	13
15	PP-1/8	1	0.022 - Condition 2	3	6	47	22
15	PP-1/8	1	0.022 - Condition 2	3	7	55	30
15	PP-1/8	1	0.022 - Condition 2	3	8	66	41
15	PP-1/8	1	0.022 - Condition 2	3	9	83	58

* Condition No. 1 - Nicks
Condition No. 2 - Pin Holes
Condition No. 3 - Scratches
1 Copper Discolored at 210° F.

TABLE XVII (CONT)

TEMPERATURE RISE VS CURRENT ON PAPER PHENOLIC (1/8 INCH THICKNESS - 1 OZ.) COPPER

Board No.	Board Type & Thickness (Inch)	Copper Weight (Oz.)	Reduction of Copper Conductor at Point of Measurement-(Inches) *(Due to Condition No.)	Time In (Min.)	Ampere I (Amps.)	Temperature (C^o)	Temperature Rise In ^oC (Above Ambient - 25^oC)
15	PP-1/8	1	0.022 - Condition 2	3	[2] 10	108	83
15	PP-1/8	1	0.022 - Condition 2	1	11	121	96
15	PP-1/8	1	0.025 - Condition 3	0	0	0	0
15	PP-1/8	1	0.025 - Condition 3	4	1	26	1
15	PP-1/8	1	0.025 - Condition 3	4	2	26	1
15	PP-1/8	1	0.025 - Condition 3	4	3	29	4
15	PP-1/8	1	0.025 - Condition 3	3	4	33	8
15	PP-1/8	1	0.025 - Condition 3	3	5	40	15
15	PP-1/8	1	0.025 - Condition 3	3	6	45	20
15	PP-1/8	1	0.025 - Condition 3	3	7	59	34
15	PP-1/8	1	0.025 - Condition 3	3	8	71	46
15	PP-1/8	1	0.025 - Condition 3	3	9	88	63
15	PP-1/8	1	0.025 - Condition 3	3	10	[3] 110	85
15	PP-1/8	1	0.025 - Condition 3	1	11	122	97

* Condition No. 1 - Nicks
Condition No. 2 - Pin Holes
Condition No. 3 - Scratches
2 Copper Discolored at 210° F.
3 Copper Discolored at 210° F.

TABLE XVIII

TEMPERATURE RISE VS. CURRENT ON PAPER PHENOLIC (1/8 INCH THICKNESS - 2 OZ.) COPPER

Board No.	Board Type & Thickness (Inch)	Copper Weight (Oz.)	Reduction of Copper Conductor at Point of Measurement-(Inches) *(Due to Condition No.)	Time In (Min.)	Ampere I (Amps.)	Temperature (C°)	Temperature Rise In °C (Above Ambient - 25°C)
16	PP-1/8	2	0.022 - Condition 1	0	0	0	0
16	PP-1/8	2	0.022 - Condition 1	5	1	26	1
16	PP-1/8	2	0.022 - Condition 1	4	2	28	3
16	PP-1/8	2	0.022 - Condition 1	4	3	29	4
16	PP-1/8	2	0.022 - Condition 1	4	4	32	7
16	PP-1/8	2	0.022 - Condition 1	4	5	35	10
16	PP-1/8	2	0.022 - Condition 1	4	6	40	15
16	PP-1/8	2	0.022 - Condition 1	4	7	37	22
16	PP-1/8	2	0.022 - Condition 1	4	8	55	30
16	PP-1/8	2	0.022 - Condition 1	4	9	64	39
16	PP-1/8	2	0.022 - Condition 1	4	[1] 10	76	51
16	PP-1/8	2	0.022 - Condition 1	4	11	92	67
16	PP-1/8	2	0.022 - Condition 1	4	12	108	83
16	PP-1/8	2	0.022 - Condition 1	1	13	122	97

* Condition No. 1 - Nicks
Condition No. 2 - Pin Holes
Condition No. 3 - Scratches
1 Copper Discolored at 200° F.

TABLE XVIII (CONT)

TEMPERATURE RISE VS. CURRENT ON PAPER PHENOLIC (1/8 INCH THICKNESS - 2 OZ.) COPPER

Board No.	Board Type & Thickness (Inch)	Copper Weight (Oz.)	Reduction of Copper Conductor at Point of Measurement-(Inches) *(Due to Condition No.)	Time In (Min.)	Ampere I (Amps.)	Temperature (C°)	Temperature Rise In °C (Above Ambient - 25°C)
16	PP-1/8	2	0.030 - Condition 2	4	1	26	1
16	PP-1/8	2	0.030 - Condition 2	4	2	26	1
16	PP-1/8	2	0.030 - Condition 2	4	3	26.5	1.5
16	PP-1/8	2	0.030 - Condition 2	4	4	28	3
16	PP-1/8	2	0.030 - Condition 2	4	5	30	5
16	PP-1/8	2	0.030 - Condition 2	4	6	34	9
16	PP-1/8	2	0.030 - Condition 2	4	7	39	14
16	PP-1/8	2	0.030 - Condition 2	4	8	46	21
16	PP-1/8	2	0.030 - Condition 2	4	9	53	28
16	PP-1/8	2	0.030 - Condition 2	4	10	63	38
16	PP-1/8	2	0.030 - Condition 2	4	11	74	49
16	PP-1/8	2	0.030 - Condition 2	4	[2] 12	88	63
16	PP-1/8	2	0.030 - Condition 2	4	13	108	83
16	PP-1/8	2	0.030 - Condition 2	1	14	118	93

* Condition No. 1 - Nicks
Condition No. 2 - Pin Holes
Condition No. 3 - Scratches
2 Copper Discolored at 198° F.

TABLE XVIII (CONT)

TEMPERATURE RISE VS. CURRENT ON PAPER PHENOLIC (1/8 INCH THICKNESS - 2 OZ.) COPPER

Board No.	Board Type & Thickness (Inch)	Copper Weight (Oz.)	Reduction of Copper Conductor at Point of Measurement-(Inches) *(Due to Condition No.)	Time In (Min.)	Ampere I (Amps.)	Temperature (C°)	Temperature Rise In °C (Above Ambient - 25°C)
16	PP-1/8	2	0.035 - Condition 3	4	1	27	2
16	PP-1/8	2	0.035 - Condition 3	4	2	28	3
16	PP-1/8	2	0.035 - Condition 3	4	3	29	4
16	PP-1/8	2	0.035 - Condition 3	4	4	30	5
16	PP-1/8	2	0.035 - Condition 3	4	5	31	6
16	PP-1/8	2	0.035 - Condition 3	4	6	33	8
16	PP-1/8	2	0.035 - Condition 3	4	7	37	12
16	PP-1/8	2	0.035 - Condition 3	4	8	40	15
16	PP-1/8	2	0.035 - Condition 3	4	9	43	18
16	PP-1/8	2	0.035 - Condition 3	4	10	49	24
16	PP-1/8	2	0.035 - Condition 3	4	11	56	31
16	PP-1/8	2	0.035 - Condition 3	4	12	62	37
16	PP-1/8	2	0.035 - Condition 3	4	13	71	46
16	PP-1/8	2	0.035 - Condition 3	4	14	79	54
16	PP-1/8	2	0.035 - Condition 3	4	[3] 15	91	66
16	PP-1/8	2	0.035 - Condition 3	4	16	121	96

* Condition No. 1 - Nicks
Condition No. 2 - Pin Holes
Condition No. 3 - Scratches
3 Copper Discolored at 214° F.

TABLE XIX

TEMPERATURE RISE VS. CURRENT ON PAPER EPOXY (1/8 INCH THICKNESS - 2 OZ.) COPPER

Board No.	Board Type & Thickness (Inch)	Copper Weight (Oz.)	Reduction of Copper Conductor at Point of Measurement-(Inches) *(Due to Condition No.)	Time In (Min.)	Ampere (Amps.)	Temperature (C^o)	Temperature Rise In ^oC (Above Ambient -25^oC)
17	PX - 1/8	2	0.0250 - Condition 1	0	0	0	0
17	PX - 1/8	2	0.0250 - Condition 1	4	1	26	1
17	PX - 1/8	2	0.0250 - Condition 1	3	2	27	2
17	PX - 1/8	2	0.0250 - Condition 1	3	3	28	3
17	PX - 1/8	2	0.0250 - Condition 1	3	4	30	5
17	PX - 1/8	2	0.0250 - Condition 1	3	5	33	8
17	PX - 1/8	2	0.0250 - Condition 1	3	6	39	14
17	PX - 1/8	2	0.0250 - Condition 1	3	7	43	18
17	PX - 1/8	2	0.0250 - Condition 1	3	8	49	24
17	PX - 1/8	2	0.0250 - Condition 1	3	9	55	30
17	PX - 1/8	2	0.0250 - Condition 1	3	10	64	39
17	PX - 1/8	2	0.0250 - Condition 1	3	11	72	47
17	PX - 1/8	2	0.0250 - Condition 1	3	12	83	58
17	PX - 1/8	2	0.0250 - Condition 1	3	[1] 13	102	77

* Condition No. 1 - Nicks
Condition No. 2 - Pin Holes
Condition No. 3 - Scratches
1 Copper Discolored at 200^o F.

TABLE XIX (CONT)

TEMPERATURE RISE VS. CURRENT ON PAPER EPOXY (1/8 INCH THICKNESS - 2 OZ.) COPPER

Board No.	Board Type & Thickness (Inch)	Copper Weight (Oz.)	Reduction of Copper Conductor at Point of Measurement-(Inches) *(Due to Condition No.)	Time In (Min.)	Ampere I (Amps.)	Temperature (C^o)	Temperature Rise In ^oC (Above Ambient -25^{o}C)
17	PX - 1/8	2	0.0250 - Condition 1	1	14	121	96
17	PX - 1/8	2	0.030 - Condition 2	0	0	0	0
17	PX - 1/8	2	0.030 - Condition 2	4	1	26	1
17	PX - 1/8	2	0.030 - Condition 2	3	5	32	7
17	PX - 1/8	2	0.030 - Condition 2	3	6	36	11
17	PX - 1/8	2	0.030 - Condition 2	3	7	40	15
17	PX - 1/8	2	0.030 - Condition 2	3	8	46	21
17	PX - 1/8	2	0.030 - Condition 2	3	9	53	28
17	PX - 1/8	2	0.030 - Condition 2	3	10	62	37
17	PX - 1/8	2	0.030 - Condition 2	3	11	70	45
17	PX - 1/8	2	0.030 - Condition 2	3	12	82	57
17	PX - 1/8	2	0.030 - Condition 2	3	[2]13	94	69
17	PX - 1/8	2	0.030 - Condition 2	3	14	113	88
17	PX - 1/8	2	0.030 - Condition 2	1	15	122	97

* Condition No. 1 - Nicks
Condition No. 2 - Pin Holes
Condition No. 3 - Scratches
2 Copper Discolored at 192^o F.

TABLE XIX (CONT)

TEMPERATURE RISE VS. CURRENT ON PAPER EPOXY (1/8 INCH THICKNESS - 2OZ.) COPPER

Board No.	Board Type & Thickness (Inch)	Copper Weight (Oz.)	Reduction of Copper Conductor at Point of Measurement-(Inches) *(Due to Condition No.)	Time In (Min.)	(Amps.)	Temperature (C°)	Temperature Rise In °C (Above Ambient -25°C)
17	PX - 1/8	2	0.0400 - Condition 3	0	0	0	0
17	PX - 1/8	2	0.0400 - Condition 3	4	1	27	2
17	PX - 1/8	2	0.0400 - Condition 3	3	5	32	7
17	PX - 1/8	2	0.0400 - Condition 3	3	6	34	9
17	PX - 1/8	2	0.0400 - Condition 3	3	7	38	13
17	PX - 1/8	2	0.0400 - Condition 3	3	8	49	24
17	PX - 1/8	2	0.0400 - Condition 3	3	9	57	32
17	PX - 1/8	2	0.0400 - Condition 3	3	10	64	39
17	PX - 1/8	2	0.0400 - Condition 3	3	11	74	49
17	PX - 1/8	2	0.0400 - Condition 3	3	12	85	60
17	PX - 1/8	2	0.0400 - Condition 3	3	[3] 13	97	72
17	PX - 1/8	2	0.0400 - Condition 3	3	14	116	91
17	PX - 1/8	2	0.0400 - Condition 3	1	15	126	101

* Condition No. 1 - Nicks
Condition No. 2 - Pin Holes
Condition No. 3 - Scratches

3 Copper Discolored at 196° F.

TABLE XX

TEMPERATURE RISE VS. CURRENT ON GLASS EPOXY (1/8 INCH THICKNESS - 1 OZ.) COPPER

Board No.	Board Type & Thickness (Inch)	Copper Weight (Oz.)	Reduction of Copper Conductor at Point of Measurement-(Inches) *(Due to Condition No.)	Time In (Min.)	Ampere I (Amps.)	Temperature (C^o)	Temperature Rise In ^oC (Above Ambient -25^oC)
18	GE - 1/8	1	0.0200 - Condition 1	0	0	0	0
18	GE - 1/8	1	0.0200 - Condition 1	4	1	27	2
18	GE - 1/8	1	0.0200 - Condition 1	3	5	40	15
18	GE - 1/8	1	0.0200 - Condition 1	3	6	52	27
18	GE - 1/8	1	0.0200 - Condition 1	3	7	66	41
18	GE - 1/8	1	0.0200 - Condition 1	3	8	79	54
18	GE - 1/8	1	0.0200 - Condition 1	3	9	100	75
18	GE - 1/8	1	0.0200 - Condition 1	1	[1] 10	121	96
18	GE - 1/8	1	0.0250 - Condition 2	4	1	26	1
18	GE - 1/8	1	0.0250 - Condition 2	3	5	37	12
18	GE - 1/8	1	0.0250 - Condition 2	3	6	46	21
18	GE - 1/8	1	0.0250 - Condition 2	3	7	59	34
18	GE - 1/8	1	0.0250 - Condition 2	3	8	71	46
18	GE - 1/8	1	0.0250 - Condition 2	3	9	93	68

* Condition No. 1 - Nicks
Condition No. 2 - Pin Holes
Condition No. 3 - Scratches

1 Copper Discolored at 238° F.

TABLE XX (CONT)

TEMPERATURE RISE VS. CURRENT ON GLASS EPOXY (1 8 INCH THICKNESS - 1 OZ.) COPPER

Board No.	Board Type & Thickness (Inch)	Copper Weight (Oz.)	Reduction of Copper Conductor at Point of Measurement-(Inches) *(Due to Condition No.)	Time In (Min.)	Ampere I (Amps.)	Temperature (C°)	Temperature Rise In °C (Above Ambient -25°C)
18	GE - 1/8	1	0.0250 - Condition 2	3	[2] 10	113	88
18	GE - 1/8	1	0.0250 - Condition 2	1	11	121	96
18	GE - 1/8	1	0.0300 - Condition 3	4	1	26	1
18	GE - 1/8	1	0.0300 - Condition 3	3	5	41	16
18	GE - 1/8	1	0.0300 - Condition 3	3	6	53	28
18	GE - 1/8	1	0.0300 - Condition 3	3	7	65	40
18	GE - 1/8	1	0.0300 - Condition 3	3	8	82	57
18	GE - 1/8	1	0.0300 - Condition 3	3	[3] 9	98	73
18	GE - 1/8	1	0.0300 - Condition 3	2	10	122	97

* Condition No. 1 - Nicks
Condition No. 2 - Pin Holes
Condition No. 3 - Scratches
2 Copper Discolored at 216° F.
3 Copper Discolored at 206° F.

TABLE XXI

TEMPERATURE RISE VS. CURRENT ON GLASS EPOXY (1/8 INCH THICKNESS - 2 OZ.) COPPER

Board No.	Board Type & Thickness (Inch)	Copper Weight (Oz.)	Reduction of Copper Conductor at Point of Measurement-(Inches) *(Due to Condition No.)	Time In (Min.)	Ampere I (Amps.)	Temperature (C^o)	Temperature Rise In ^oC (Above Ambient -25^oC)
19	GE - 1/8	2	0.0250 - Condition 1	0	0	0	0
19	GE - 1/8	2	0.0250 - Condition 1	4	1	26	1
19	GE - 1/8	2	0.0250 - Condition 1	4	5	30	5
19	GE - 1/8	2	0.0250 - Condition 1	3	6	34	9
19	GE - 1/8	2	0.0250 - Condition 1	3	7	37	12
19	GE - 1/8	2	0.0250 - Condition 1	3	8	41	16
19	GE - 1/8	2	0.0250 - Condition 1	3	9	47	22
19	GE - 1/8	2	0.0250 - Condition 1	3	10	53	28
19	GE - 1/8	2	0.0250 - Condition 1	3	11	62	37
19	GE - 1/8	2	0.0250 - Condition 1	3	12	69	44
19	GE - 1/8	2	0.0250 - Condition 1	3	13	80	55.
19	GE - 1/8	2	0.0250 - Condition 1	3	14	93	68
19	GE - 1/8	2	0.0250 - Condition 1	3	[1]15	111	86
19	GE - 1/8	2	0.0250 - Condition 1	2	16	123	98

* Condition No. 1 - Nicks
Condition No. 2 - Pin Holes
Condition No. 3 - Scratches
1 Copper Discolored at 230^o F.

TABLE XXI (CONT)

TEMPERATURE RISE VS. CURRENT ON GLASS EPOXY (1 8 INCH THICKNESS - 2 OZ.) COPPER

Board No.	Board Type & Thickness (Inch)	Copper Weight (Oz.)	Reduction of Copper Conductor at Point of Measurement-(Inches) *(Due to Condition No.)	Time In (Min.)	Ampere I (Amps.)	Temperature (C°)	Temperature Rise In °C (Above Ambient -25°C)
19	GE - 1/8	2	0.0450 - Condition 2	3	[2] 15	101	76
19	GE - 1/8	2	0.0450 - Condition 2	3	16	115	90
19	GE - 1/8	2	0.0450 - Condition 2	3	17	122	97
19	GE - 1/8	2	0.0250 - Condition 3	4	1	26	1
19	GE - 1/8	2	0.0250 - Condition 3	4	5	40	15
19	GE - 1/8	2	0.0250 - Condition 3	3	6	42	17
19	GE - 1/8	2	0.0250 - Condition 3	3	7	47	22
19	GE - 1/8	2	0.0250 - Condition 3	3	8	54	29
19	GE - 1/8	2	0.0250 - Condition 3	3	9	61	36
19	GE - 1/8	2	0.0250 - Condition 3	3	10	70	45
19	GE - 1/8	2	0.0250 - Condition 3	3	11	79	54
19	GE - 1/8	2	0.0250 - Condition 3	3	12	90	65
19	GE - 1/8	2	0.0250 - Condition 3	3	13	98	73
19	GE - 1/8	2	0.0250 - Condition 3	3	[3] 14	112	87
19	GE - 1/8	2	0.0250 - Condition 3	3	15	124	99

* Condition No. 1 - Nicks
Condition No. 2 - Pin Holes
Condition No. 3 - Scratches
2 Copper Discolored at 208° F.
3 Copper Discolored at 228° F.

TABLE XXI (CONT)

TEMPERATURE RISE VS. CURRENT ON GLASS EPOXY (1/8 INCH THICKNESS - 2 OZ.) COPPER

Board No.	Board Type & Thickness (Inch)	Copper Weight (Oz.)	Reduction of Copper Conductor at Point of Measurement-(Inches) *(Due to Condition No.)	Time In (Min.)	Ampere I (Amps.)	Temperature (C^o)	Temperature Rise In ^oC (Above Ambient -25^{o}C)
19	GE - 1/8	2	0.0450 - Condition 2	4	1	25.5	0.5
19	GE - 1/8	2	0.0450 - Condition 2	4	2	26	1
19	GE - 1/8	2	0.0450 - Condition 2	3	3	28	3
19	GE - 1/3	2	0.0450 - Condition 2	3	4	30	5
19	GE - 1/8	2	0.0450 - Condition 2	3	5	31	6
19	GE - 1/8	2	0.0450 - Condition 2	3	6	33	8
19	GE - 1/8	2	0.0450 - Condition 2	3	7	36	11
19	GE - 1/8	2	0.0450 - Condition 2	3	8	42	17
19	GE - 1/8	2	0.0450 - Condition 2	3	9	45	20
19	GE - 1/8	2	0.0450 - Condition 2	3	10	51	26
19	GE - 1/8	2	0.0450 - Condition 2	3	11	58	33
19	GE - 1/8	2	0.0450 - Condition 2	3	12	65	40
19	GE - 1/8	2	0.0450 - Condition 2	3	13	75	50
19	GE - 1/8	2	0.0450 - Condition 2	3	14	86	61

* Condition No. 1 - **Nicks**
Condition No. 2 - **Pin Holes**
Condition No. 3 - **Scratches**

TABLE XXII

TEMPERATURE RISE VS. CURRENT ON GLASS SILICONE (1/8 INCH THICKNESS - 1 OZ.) COPPER

Board No.	Board Type & Thickness (Inch)	Copper Weight (Oz.)	Reduction of Copper Conductor at Point of Measurement-(Inches) *(Due to Condition No.)	Time In (Min.)	Ampere I (Amps.)	Temperature (C°)	Temperature Rise In °C (Above Ambient -25°C)
20	GS - 1/8	1	0.0250 - Condition 1	0	0	0	0
20	GS - 1/8	1	0.0250 - Condition 1	5	1	27	2
20	GS - 1/8	1	0.0250 - Condition 1	4	5	43	18
20	GS - 1/8	1	0.0250 - Condition 1	3	6	52	27
20	GS - 1/8	1	0.0250 - Condition 1	3	7	65	40
20	GS - 1/8	1	0.0250 - Condition 1	3	8	81	56
20	GS - 1/8	1	0.0250 - Condition 1	3	9	103	78
20	GS - 1/8	1	0.0250 - Condition 1	1	[1] 10	122	97
20	GS - 1/8	1	0.0250 - Condition 2	5	1	26	1
20	GS - 1/8	1	0.0250 - Condition 2	4	5	42	17
20	GS - 1/8	1	0.0250 - Condition 2	3	6	50	25
20	GS - 1/8	1	0.0250 - Condition 2	3	7	64	39
20	GS - 1/8	1	0.0250 - Condition 2	3	8	83	58
20	GS - 1/8	1	0.0250 - Condition 2	3	9	103	78

* Condition No. 1 - Nicks
Condition No. 2 - Pin Holes
Condition No. 3 - Scratches
1 Copper Discolored at 250° F.

TABLE XXII (CONT)

TEMPERATURE RISE VS. CURRENT ON GLASS SILICONE (1/8 INCH THICKNESS - 1 OZ.) COPPER

Board No.	Board Type & Thickness (Inch)	Copper Weight (Oz.)	Reduction of Copper Conductor at Point of Measurement-(Inches) *(Due to Condition No.)	Time In (Min.)	Ampere I (Amps.)	Temperature (C^o)	Temperature Rise In ^oC (Above Ambient -25^oC)
20	GS - 1/8	1	0.0250 - Condition 2	1	[2] 10	123	98
20	GS - 1/8	1	0.0380 - Condition 3	5	1	26	1
20	GS - 1/8	1	0.0380 - Condition 3	4	5	42	17
20	GS - 1/8	1	0.0380 - Condition 3	3	6	52	27
20	GS - 1/8	1	0.0380 - Condition 3	3	7	66	41
20	GS - 1/8	1	0.0380 - Condition 3	3	8	82	57
20	GS - 1/8	1	0.0380 - Condition 3	3	9	106	81
20	GS - 1/8	1	0.0380 - Condition 3	3	[3] 10	121	96

* Condition No. 1 - Nicks
Condition No. 2 - Pin Holes
Condition No. 3 - Scratches

2 Copper Discolored at 250^o F.
3 Copper Discolored at 250^o F.

TABLE XXIII

TEMPERATURE RISE VS. CURRENT ON GLASS SILICONE (1/8 INCH THICKNESS - 2 OZ.) COPPER

Board No.	Board Type & Thickness (Inch)	Copper Weight (Oz.)	Reduction of Copper Conductor at Point of Measurement-(Inches) *(Due to Condition No.)	Time In (Min.)	Ampere I (Amps.)	Temperature (C°)	Temperature Rise In °C (Above Ambient -25°C)
21	GS - 1/8	2	0.0250 - Condition 1	0	0	0	0
21	GS - 1/8	2	0.0250 - Condition 1	3	1	26	1
21	GS - 1/8	2	0.0250 - Condition 1	4	5	32	7
21	GS - 1/8	2	0.0250 - Condition 1	4	6	35	10
21	GS - 1/8	2	0.0250 - Condition 1	4	7	40	15
21	GS - 1/8	2	0.0250 - Condition 1	4	8	45	20
21	GS - 1/8	2	0.0250 - Condition 1	4	9	51	26
21	GS - 1/8	2	0.0250 - Condition 1	4	10	60	35
21	GS - 1/8	2	0.0250 - Condition 1	4	11	70	45
21	GS - 1/8	2	0.0250 - Condition 1	4	12	82	57
21	GS - 1/8	2	0.0250 - Condition 1	4	[1] 13	96	71
21	GS - 1/8	2	0.0250 - Condition 1	4	14	115	90
21	GS - 1/8	2	0.0250 - Condition 1	4	15	123	98
21	GS - 1/8	2	0.0250 - Condition 2	4	1	26	1

* Condition No. 1 - Nicks
Condition No. 2 - Pin Holes
Condition No. 3 - Scratches
1 Copper Discolored at 200° F.

TABLE XXIII (CONT)

TEMPERATURE RISE VS. CURRENT ON GLASS SILICONE (1/8 INCH THICKNESS - 2 OZ.) COPPER

Board No.	Board Type & Thickness (Inch)	Copper Weight (Oz.)	Reduction of Copper Conductor at Point of Measurement-(Inches) *(Due to Condition No.)	Time In (Min.)	Ampere I (Amps.)	Temperature (C°)	Temperature Rise In °C (Above Ambient -25°C)
21	GS - 1/8	2	0.0250 - Condition 2	3	5	29	4
21	GS - 1/8	2	0.0250 - Condition 2	3	6	33	8
21	GS - 1/8	2	0.0250 - Condition 2	3	7	38	13
21	GS - 1/8	2	0.0250 - Condition 2	3	8	42	17
21	GS - 1/8	2	0.0250 - Condition 2	3	9	48	23
21	GS - 1/8	2	0.0250 - Condition 2	3	10	56	31
21	GS - 1/8	2	0.0250 - Condition 2	3	11	64	39
21	GS - 1/8	2	0.0250 - Condition 2	3	12	72	47
21	GS - 1/8	2	0.0250 - Condition 2	3	13	84	59
21	GS - 1/8	2	0.0250 - Condition 2	3	14	96	71
21	GS - 1/8	2	0.0250 - Condition 2	3	[2] 15	114	89
21	GS - 1/8	2	0.0250 - Condition 2	1	16	121	96
21	GS - 1/8	2	0.0200 - Condition 3	4	1	26	1
21	GS - 1/8	2	0.0200 - Condition 3	3	5	32	7

* Condition No. 1 - Nicks
Condition No. 2 - Pin Holes
Condition No. 3 - Scratches
2 Copper Discolored at 218° F.

TABLE XXIII (CONT)

TEMPERATURE RISE VS. CURRENT ON GLASS SILICONE (1/8 INCH THICKNESS - 2 OZ.) COPPER

Board No.	Board Type & Thickness (Inch)	Copper Weight (Oz.)	Reduction of Copper Conductor at Point of Measurement-(Inches) *(Due to Condition No.)	Time In (Min.)	Ampere I (Amps.)	Temperature (C°)	Temperature Rise In °C (Above Ambient -25°C)
21	GS - 1/8	2	0.0200 - Condition 3	3	6	35	10
21	GS - 1/8	2	0.0200 - Condition 3	3	7	39	14
21	GS - 1/8	2	0.0200 - Condition 3	3	8	43	18
21	GS - 1/8	2	0.0200 - Condition 3	3	9	49	24
21	GS - 1/8	2	0.0200 - Condition 3	3	10	56	31
21	GS - 1/8	2	0.0200 - Condition 3	3	11	65	40
21	GS - 1/8	2	0.0200 - Condition 3	3	12	75	50
21	GS - 1/8	2	0.0200 - Condition 3	3	13	87	62
21	GS - 1/8	2	0.0200 - Condition 3	3	[3] 14	102	77
21	GS - 1/8	2	0.0200 - Condition 3	3	15	121	96

* Condition No. 1 - Nicks
Condition No. 2 - Pin Holes
Condition No. 3 - Scratches
3 Copper Discolored at 198° F.

The test results on boards 15 through 21 show an average temperature rise above ambient for 1 and 2 oz. copper of 65°C., measured at the points of maximum conductor cross-sectional reduction. This point, while indicating the first visible evidence of damage to the conductor from heat, is still well below the actual temperature of destructive separation of the conductor from the base laminate. In view of this, it would seem that the original premise of an allowable temperature rise of 40°C above ambient was reasonable, and is derated sufficiently to allow an adequate safety margin. It is recommended that this figure be retained as a maximum allowable temperature rise above ambient for both 1 and 2 ounce copper conductors.

From the data presented in Tables XVII through XXIII and data plotted in Figures No. 33 and 34, a maximum of 40°C temperature rise above ambient for both 1 and 2 oz. copper is recommended for both of these copper weights.

2.6 Conclusions

The following conclusions are based on the work performed and test results reported under Task A:

1. A 50% reduction in conductor cross-section area has very little effect on the apparent temperature increase of copper conductor line width from 0.047 to 0.100 of an inch, within a range of current values which do not allow an overall increase in temperature beyond 40°C above ambient.

2. Multiple notches in a single copper conductor apparently will not have any further effect on temperature rise than a single notch in a copper conductor. (When the area of the notch is the same in each case.)

3. A 40°C temperature rise for both 1 and 2 oz. copper (above ambient) for conductor line width of .020 to .100 or greater was found to be a safe temperature rise limit without destruction to either the copper conductor or base laminate.

4. It is apparent, both from temperature rise values established from special copper conductor test strips, and from conventional boards tested that copper conductors produced on various base laminates will vary in temperature rise and temperature at which the copper conductor will lift from the base material. It is most logical to assume (based on temperature rise, peel strength data, and destructive tests) that the base laminate resin and reinforcement have an influence on the temperature rise of a copper conductor, peel strength and temperature at which a conductor will separate from the base laminate.

The following statements can be made about the influence of paper and glass base laminates on temperature rise, peel strength and temperature at which copper conductor will lift from the base laminate:

a) 1 and 2 oz. copper on a paper base laminate (using a phenolic resin system) gives a lower peel strength than glass base laminate when subjected to temperature rise vs current measurements.

b) 1 and 2 oz. copper conductors on glass base laminates (using epoxy or silicone resin system) will give approximately 1 to 2 pounds per inch width greater pull strength when tested after temperature rise measurements.

c) 1 and 2 oz. copper conductors on glass base laminates carry more current than the same copper conductors on paper base laminates.

FIGURE NO. 33 DESIGN CHART FOR DETERMINING CURRENT CARRYING CAPACITY AND TEMPERATURE RISE FOR 1 OZ. COPPER CONDUCTORS.

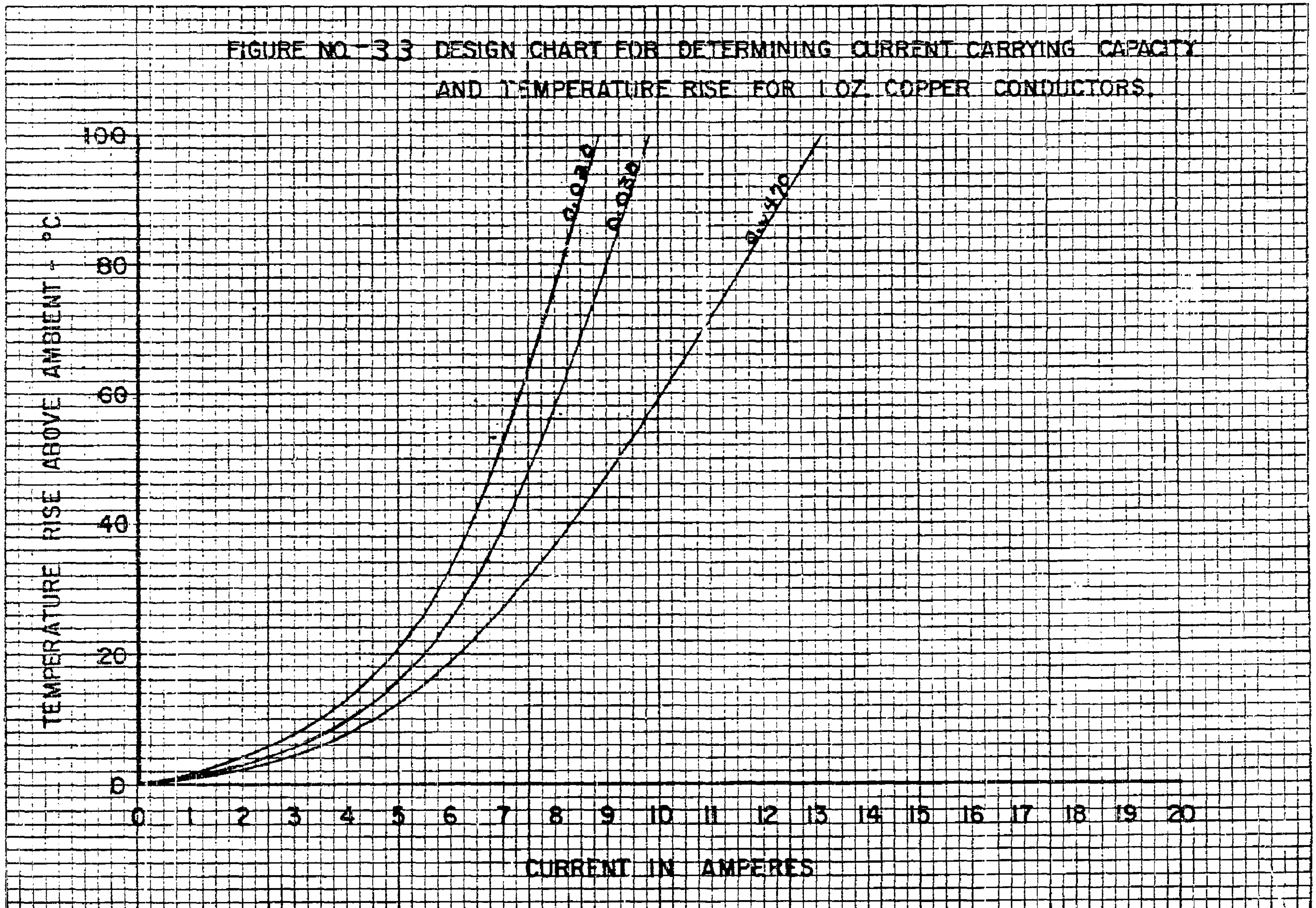
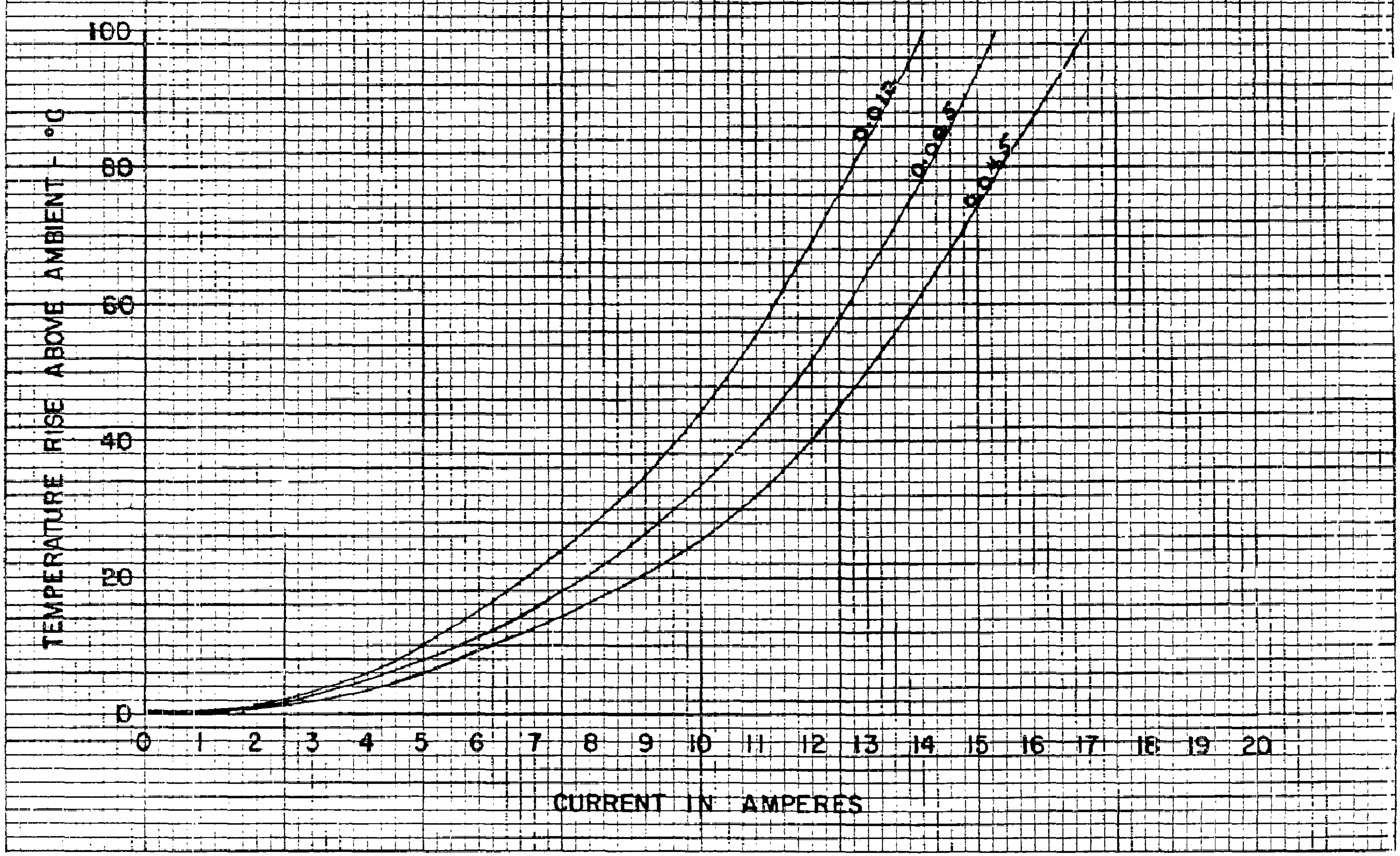


FIGURE NO. 34 DESIGN CHART FOR DETERMINING CURRENT CARRYING CAPACITY AND TEMPERATURE RISE FOR 2 OZ COPPER CONDUCTORS



Glass reinforcing material acts as a better heat sink than paper reinforcing material. One possible reason for this, is the heat capacity value for glass is higher than paper. The type of resin system will effect temperature rise measurement but the reinforcing material plays a greater role in influencing the current carrying capacity of a copper conductor before destruction.

To assure reliability and minimize the possible effects of long time application of elevated temperatures which could cause ultimate degradation of the bond to failure, the following specification limitations are recommended.

1. For any given 1 inch length of conductor, individual nicks or pin holes or combination of nicks and pin holes which expose the base laminate, or any scratch shall not reduce the cross-section area of the conductor by more than 30%.

2. For any given 1 inch length of conductor no combination of nicks or pin holes which expose the base laminate, or any scratch shall be acceptable when the cross-section area at the point of maximum reduction shows a temperature increase in excess of 40°C when examined in accordance with the procedure outlined in Appendix B.

3. Task B - Insulation Resistance

3.1 Approach

The primary purpose of this task is to evaluate "bullseye" and "comb" patterns presently being used in industry for measuring insulation resistance, to establish a method which is both practicable and reproducible in laboratories for measuring insulation resistance under humidity chamber conditions, and to compare the reproduciability of results obtained from bullseye patterns with the various comb patterns being used, when measured under these conditions.

To accomplish this, a conventional humidity chamber designed to reproduce the temperature and humidity requirements of MIL-Std-202 has been redesigned and modified to allow the simultaneous testing and measurement of a number of samples while undergoing conditioning. Special precautions were taken in the redesign to minimize the possibility of any erroneous readings resulting from leakage to the chamber or between specimens.

3.2 Specimen Fabrication

The bullseye and comb pattern test specimens were prepared according to steps outlined in Appendix B at the end of the report. The test specimens were not cleaned and dried as outlined in Appendix B but two alternate cleaning procedures were used. The purpose of having two different cleaning procedures was to see what effect, if any, a variation of cleaning after etching would have on insulation resistance of the test specimens.

The two procedures are outlined below:

3.2.1 Identification of Test Boards with Respect to Cleaning

Test boards 1 through 30 and 111 through 126 (see Table XXXII for test board type and other information) were cleaned by the following method:

1. Washed with tap water at 60 to 90°F for several minutes.

2. Scrubbed with Grade FF Pumice to remove resist and wipe with a lint free cloth moistened with methyl ethye ketone (MEK). (Care was exercised to avoid abrading the adhesive layer with the pumice.)

3. Immersed in 10% oxalic solution at 60-90°F for 15 to 20 minutes. Solution was agitated periodically.

4. Scrubbed with a plastic bristle brush under running water. (60-90°F temperature).

5. Rinsed in distilled water and dry with filtered air.

6. Specimens were than handled with nylon lint-free gloves and dried for one hour in an air circulating oven at 80° ±3°C.

Test Boards 31 through 110 were cleaned by this procedure:

1. Scrubbed with pumice or Ajax and Tempico brush.

2. Rinsed 1-2 minutes in spray water rinse.

3. Rinsed 4-6 minutes in running water rinse.

4. Immersed in versene solution (1 oz. per gallon) for 2-4 minutes.

5. Rinsed 2-4 minutes in hot (min. 155°F) deionized water.

6. Blown dry with clean filtered air and then bagged immediately.

All handling during cleaning was done with white cotton gloves.

3.3 Design of Humidity Chamber

The basic re-design of the chamber involved the replacement of two walls with removable modular units containing all of the necessary internal connections, feed-thru leads, and external tie points for electrical measurement. The internal connections consist of three spring contacts for each test board. These were originally mounted on four teflon strips, with twelve test board positions per strip. Preliminary measurements indicated that too much electrical leakage was occurring in the system and it was necessary to reduce the number of positions per strip and to cut each teflon strip into three pieces to provide air gaps. Original 20 gauge teflon insulated wire was replaced with teflon insulated shielded coaxial cable (Type RG-142V). These steps reduced the leakage to 0.03 to 0.04 x 10^{-11} amperes which was small enough to have no measurable effect on final insulation resistance values.

The teflon coaxial cables were led through the wall of the module, three for each specimen position, and brought out to a plexiglas terminal board mounted on the outside of the unit. Three banana plug jacks were provided for each internal specimen position and the teflon coax leads were soldered to these jacks. Heavy grounded copper bus bars were provided on the terminal boards to allow all positions except the one actually under measurement to be grounded. This grounding minimized the possibility of any stray currents affecting resistance readings. The specimen identification or location was done as follows: One panel was marked I, the other II. Each row was lettered, starting with letter A. Panel I, consisting of four rows, was marked A, B, C and D. In each row numbers 1 through 14 were marked below each set of three banana plug positions. For example, a specimen identified as I-B4 would mean panel I in row B position 4.

For the wiring and plug arrangement of the modular side panels, inside view of humidity test chamber showing specimen holder arrangement, and the humidity chamber Model M3.3, see Figure No. 35, 36 and 37.

Figure No. 35. Wiring and Plug Arrangement of the Modular Side Panels

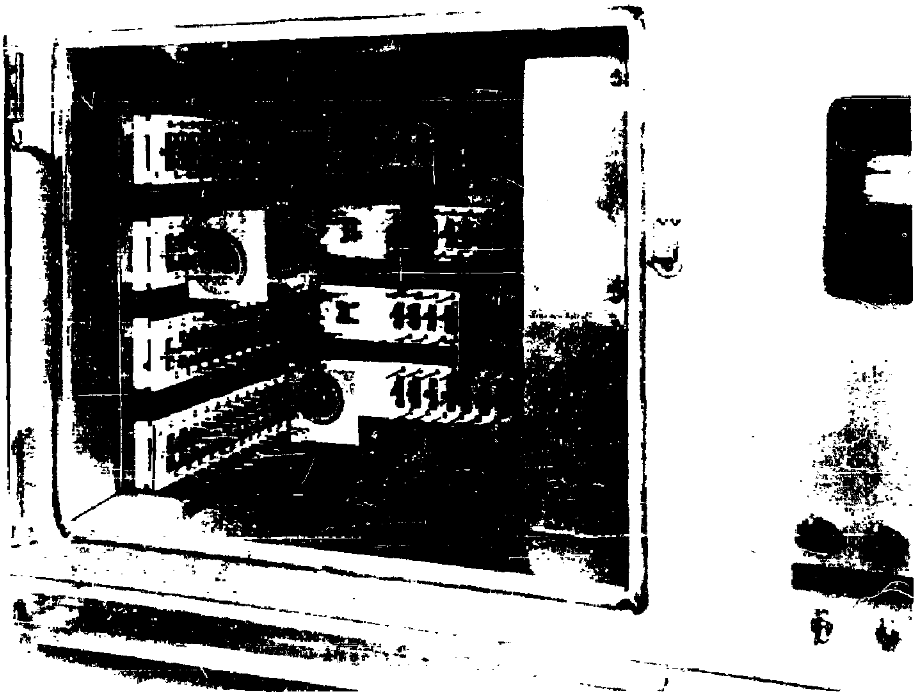


Figure No. 36. Inside View of Humidity Test Chamber Showing
Specimen Holder Arrangement

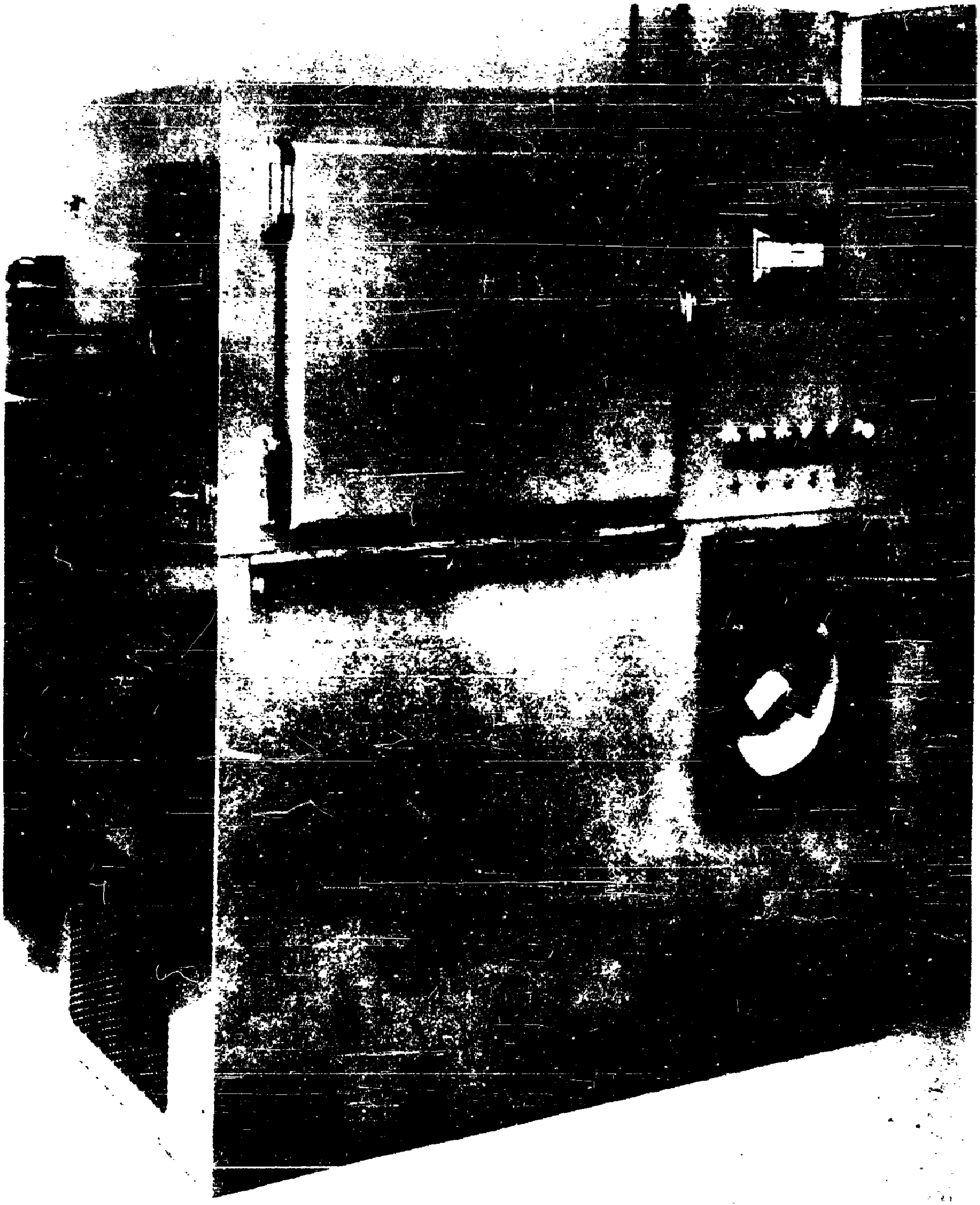


Figure No. 37. Missimers Model M3.3 Modulor Test Chamber

The following information can be seen in Figures 38, 39, 40 and 41:

1. Special design of the insulation resistance specimen holder.
2. The mounting board for test specimens.
3. The electrode connector design for the insulation resistance measurements.
4. Humidity chamber portable side panel.

3.4 Testing Procedure

3.4.1 Equipment - Because of the critical nature of the measurements which had to be made and the need for delicate and precise readings, the choice of instrumentation was vital.

Fortunately a program was already underway at the University of Delaware, sponsored jointly by EIA, ASTM and NEMA under the guidance of Professor M. A. Young, which also required the measurement of insulation resistance under chamber conditions.

A rigorous survey of available instrumentation had already been made and the results of this study were made available to us through reports and consultation. As a result it was decided to measure current and voltage through the samples rather than resistance and calculate the resistance values later. A Keithley Model 610A Electrometer was used to measure current, and the voltage was supplied by a DC Power Supply with the voltage constantly monitored by a Hewlett-Packard Model 412A Vacuum Tube Voltmeter.

3.4.2 Procedure - The Keithley Electrometer, Power Supply and the VTVM were turned on to allow a warm-up period of 30 minutes for the instruments. During any period when measurements on the test specimens were not being taken, leads of all specimens were shorted to the ground to prevent a build-up of electrostatic charge which is caused by air friction in the humidity chamber. Figure No. 42 shows the basic electrical circuit. At the end of 30 minutes, each specimen was disconnected from ground and current readings were taken. The specimen was energized with 500 volts for one minute before the current was read. Measuring insulation resistance by the indirect method enables an accuracy of $\pm 6\%$ at 10^{14} ohms range to be reached (current measured with a Keithley Electrometer Model 610A). At the end of each current reading the specimen just tested was grounded before the next specimen was measured. The 500 volt line voltage was monitored continuously with a Hewlett-Packard Model 412A Voltmeter. Referring to Figure No. 42, leads 1 and 2 are merely changed for measuring volume resistance. The insulation resistance measurements were performed on the bullseye test pattern by applying the potential across the outer and center ring of the bullseye pattern.

The insulation resistance readings on test patterns in MIL-P-55110 and SCL-6225 were taken by applying the potential across opposite leads on the test patterns respectively, making a two-electrode system.

The dimensions of the bullseye and comb test patterns are as follows:

1. Bullseye Pattern - The upper electrodes are in the shape of a circle, 2 inches in diameter. A 1/4 inch wide guard is located concentrically with respect to the upper electrode and spaced 1/4 inch from it. The bottom electrode is 3 inches in diameter with the shape of a circle.

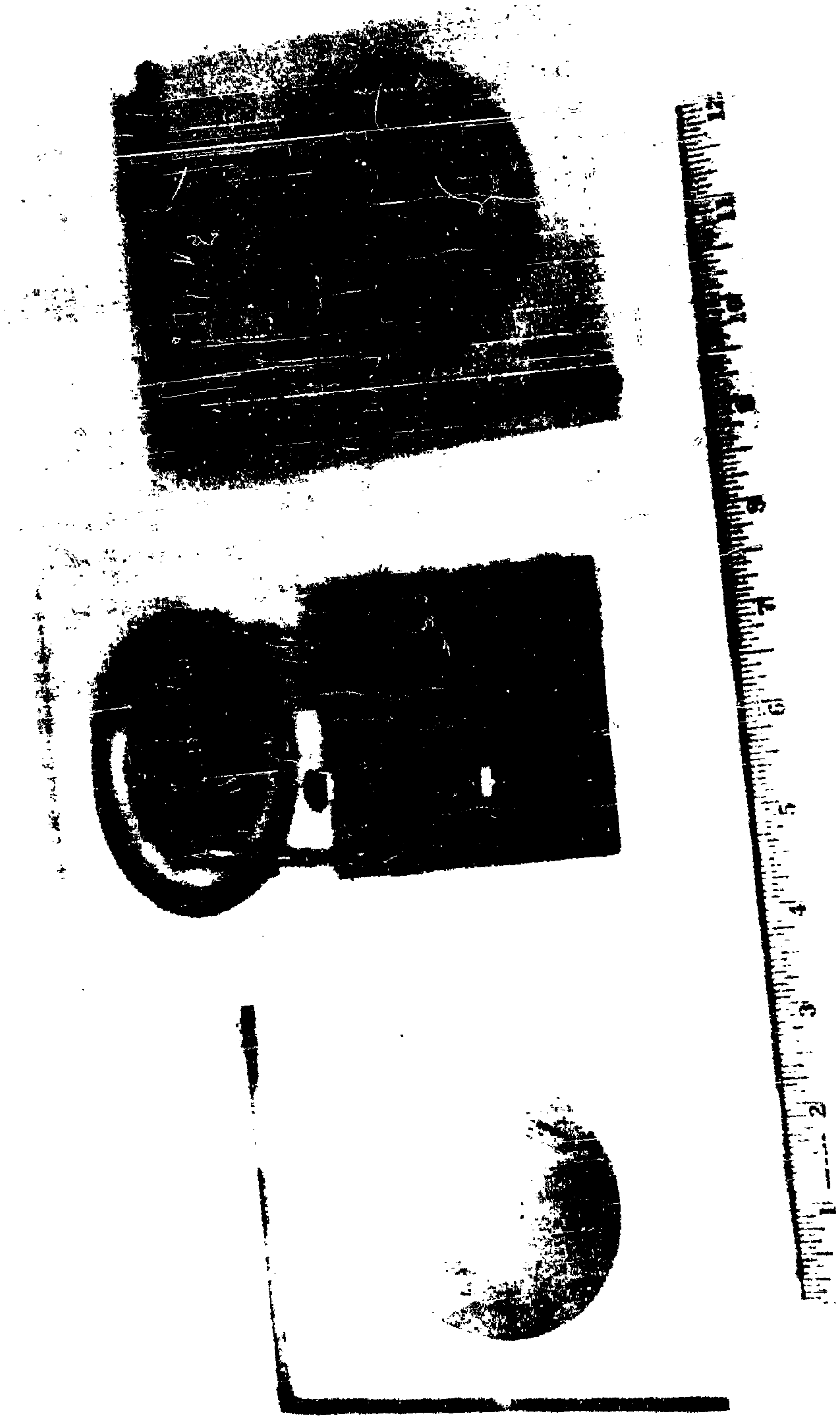


Figure No. 38. Special Design of a Specimen Holder for Use in Surface Resistance Measurements Under Humidifing and Temperature Cycling Test Conditions

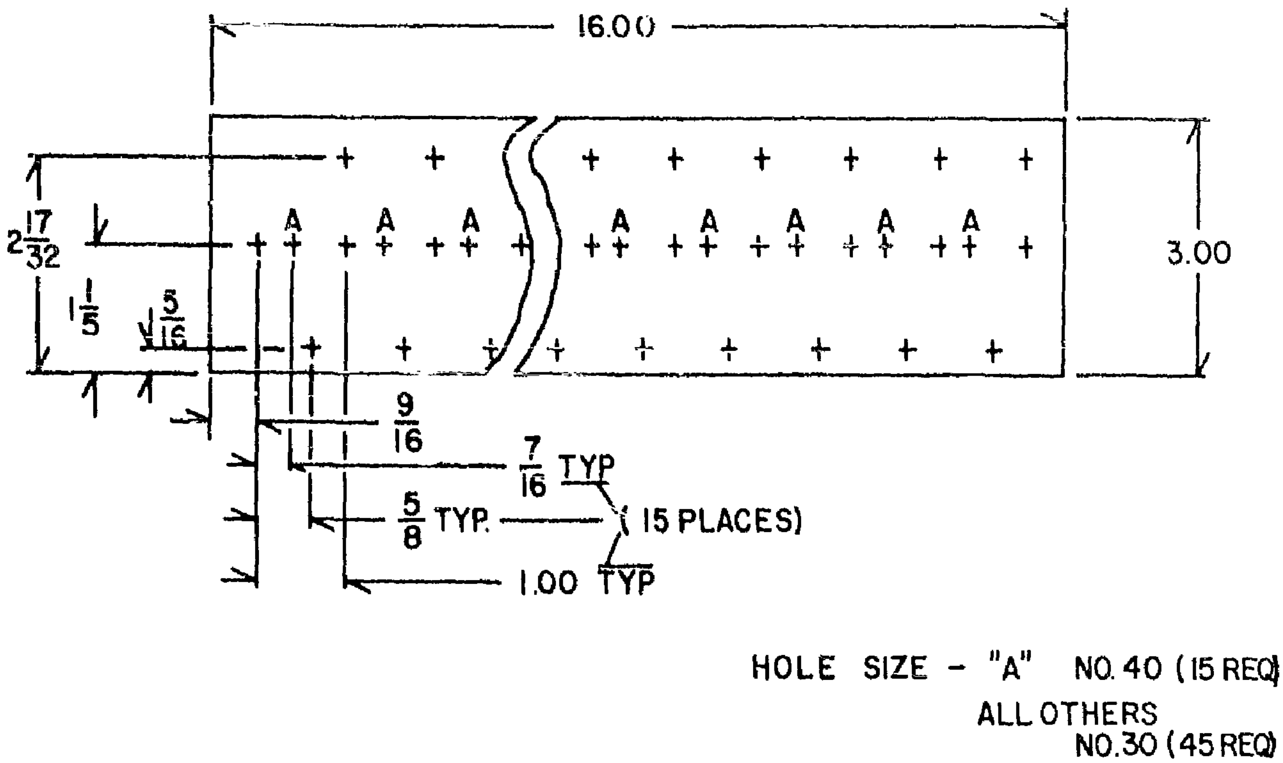


Figure No. 39. Mounting Board For Test Specimens

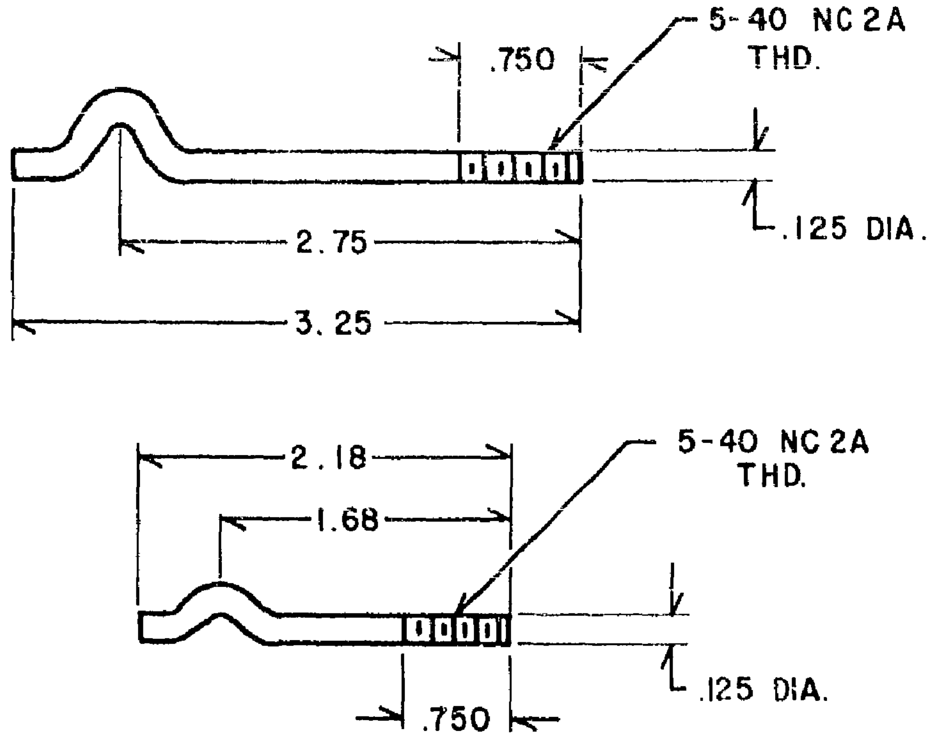


Figure No. 40. Electrode Connector Designs For
Insulation Resistance Measurements

Figure No. 41. Humidity Chamber Portable Side Panel

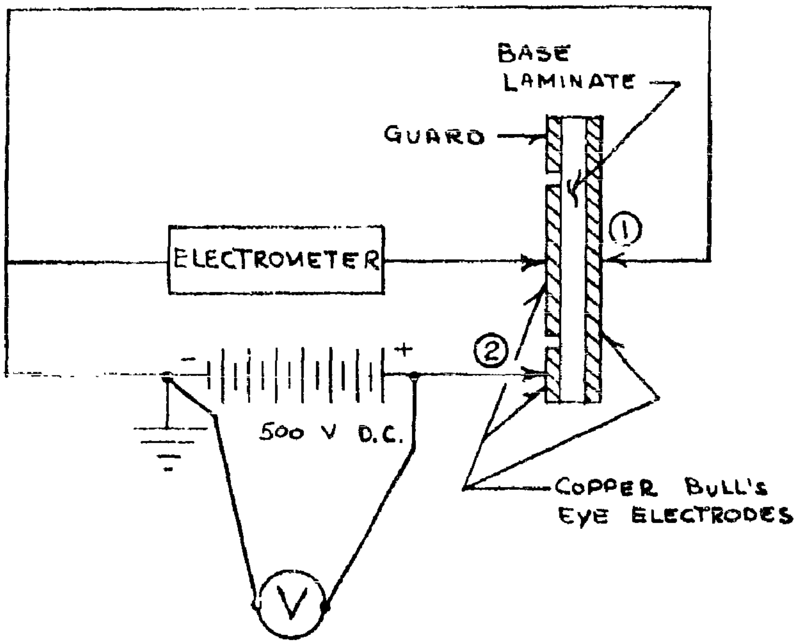


Figure No. 42. Measuring Circuit for Surface Resistance

2. Comb Pattern - This pattern is made up of five individual comb patterns, three having 5 copper conductors and two with 3 conductors. All 5 combs are meshed into one large pattern as shown in Figure No. 43 (Specimens I-H7 and H9). All of the individual conductors are 0.031 inch in width. The air gap between each conductor is 0.050 inch, and the length of each conductor is 1.3800 inches.

3. Insulation Test Pattern - (Per SCL-6225) was followed as described in Military Specification No. SCL-~~6825~~ 6225, (see Figure No. 56 for test pattern design).

4. Insulation Test Pattern - (Per MIL-P-55110) was followed as described in Military Specification No. MIL-P-55110. (See Figure No. 56 for test pattern design.)

3.5 Analysis of Insulation Test Results

Tables XXIV through XXIX show test results for two Military and one commercial comb test pattern.

Included in the comb pattern values are the insulation resistance (in megohms), measured at 100 and 500 volts DC for the test pattern from MIL-P-55110 and SCL-6225 and a commercial comb pattern. Each test pattern is marked with the military specification number or the abbreviation com. for the commercial comb test pattern.

The military patterns as detailed in SCL-6225 and MIL-P-55110 have a conductor line spacing of 0.030 in., and the specified voltage for 6225 is 100 volts DC. To enable a complete comparison to be made between these three patterns and the bullseye pattern,

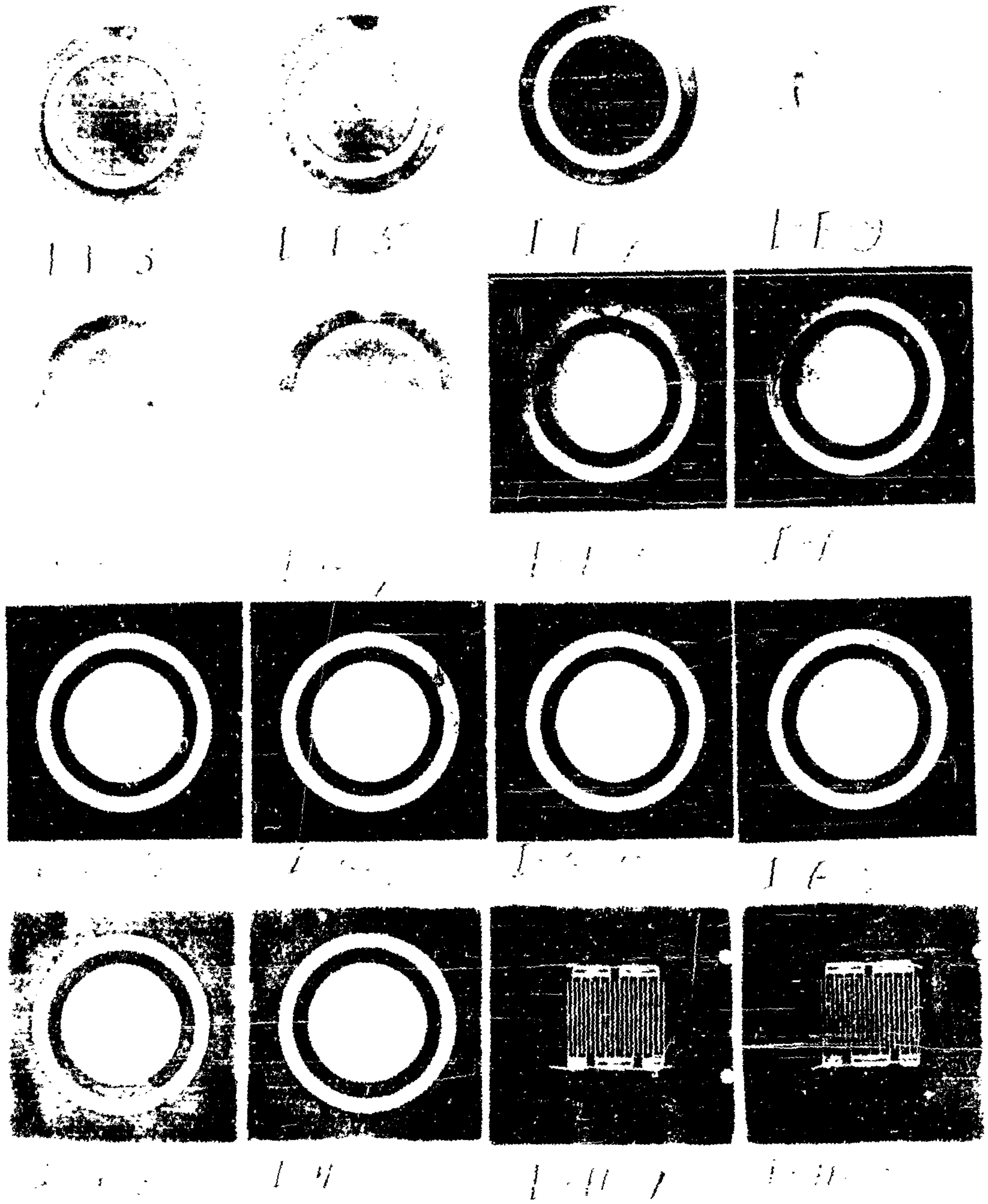


Figure No. 43. Surface Resistance Test Specimens After Humidity Test

TABLE XXIV

INSULATION RESISTANCE TEST RESULTS OF TEST PATTERN 6225 (100 VOLTS D.C.)

Board No.	Laminate Base & Pattern Design No.	INSULATION RESISTANCE (In Megohms) AT 100 VOLTS D.C. APPLIED TO EACH BOARD Initial Reading	First Day	Third Day	Fifth Day	Seventh Day	Ninth Day	Tenth Day
1	Paper Phenolic (PP) - 6225	$1.11x10^7$	$1.54x10^7$	$1.45x10^5$	$*2.38x10^6$	$1.06x10^5$	$1.02x10^5$	$2.68x10^5$
2	Paper Phenolic (PP) - 6225	$1.09x10^7$	$1.33x10^7$	$3.58x10^5$	$1.67x10^5$	$3.34x10^5$	$4.77x10^5$	$1.04x10^5$
3	Paper Phenolic (PP) - 6225	$*2.00x10^8$	$1.11x10^7$	$3.34x10^5$	$1.52x10^5$	$*1.02x10^2$	$*3.12x10^3$	$*7.14x10^4$
4	Paper Phenolic (PP) - 6225	$4.17x10^7$	$1.67x10^7$	$1.15x10^5$	$3.34x10^5$	$1.09x10^5$	$3.34x10^5$	$2.78x10^5$
5	Paper Phenolic (PP) - 6225	$2.50x10^7$	$2.86x10^7$	$1.44x10^5$	$1.52x10^5$	$1.11x10^5$	$1.45x10^5$	$1.96x10^5$
	Average Values	$2.22x10^7$	$1.70x10^7$	$2.19x10^5$	$2.01x10^5$	$1.65x10^5$	$2.64x10^5$	$2.12x10^5$
6	Glass Epoxy (GE) - 6225	$2.00x10^8$	$6.67x10^7$	$1.54x10^5$	$*3.34x10^7$	$1.02x10^5$	$2.00x10^5$	$2.86x10^5$
7	Glass Epoxy (GE) - 6225	$1.11x10^8$	$5.55x10^7$	$3.34x10^5$	$1.11x10^5$	$1.57x10^5$	$1.02x10^5$	$2.00x10^5$
8	Glass Epoxy (GE) - 6225	$3.34x10^8$	$1.67x10^7$	$1.54x10^5$	$1.25x10^5$	$1.04x10^5$	$3.32x10^5$	$1.82x10^5$
9	Glass Epoxy (GE) - 6225	$1.11x10^8$	$6.67x10^7$	$3.34x10^5$	$1.13x10^5$	$1.02x10^5$	$1.19x10^5$	$1.47x10^5$
10	Glass Epoxy (GE) - 6225	$1.25x10^8$	$1.67x10^7$	$*1.02x10^4$	$*1.04x10^4$	$*1.01x10^4$	$*1.04x10^4$	$*1.06x10^4$
	Average Values	$1.76x10^8$	$4.45x10^7$	$2.44x10^5$	$1.16x10^5$	$1.16x10^5$	$1.88x10^5$	$2.04x10^5$

* - Not averaged in total.

TABLE XXIV (CONT)

INSULATION RESISTANCE TEST RESULTS OF TEST PATTERN 6225 (100 VOLTS D.C.)

Board No.	Laminate Base & Pattern Design No.	INSULATION RESISTANCE (In Megohms) AT 100 VOLTS D.C. APPLIED TO EACH BOARD						
		Initial Reading	First Day	Third Day	Fifth Day	Seventh Day	Ninth Day	Tenth Day
11	Glass Epoxy (GB) - 6225	2.00×10^{8}	3.34×10^{7}	2.86×10^{6}	1.00×10^{5}	3.34×10^{5}	2.00×10^{5}	2.04×10^{5}
12	Glass Epoxy (GB) - 6225	1.28×10^{8}	*1.72×10^{6}	*1.76×10^{5}	8.33×10^{5}	1.67×10^{5}	1.24×10^{5}	*1.02×10^{4}
13	Glass Epoxy (GB) - 6225	2.00×10^{8}	3.58×10^{7}	1.15×10^{6}	5.00×10^{5}	2.00×10^{5}	1.10×10^{5}	*1.25×10^{4}
14	Glass Epoxy (GB) - 6225	1.79×10^{8}	3.34×10^{7}	3.23×10^{6}	1.00×10^{5}	*2.00×10^{4}	*1.11×10^{4}	1.00×10^{5}
15	Glass Epoxy (GB) - 6225	5.00×10^{8}	1.00×10^{7}	2.28×10^{6}	*4.77×10^{6}	6.56×10^{5}	1.11×10^{5}	1.19×10^{5}
	Average Values	2.41×10^{8}	2.06×10^{7}	2.38×10^{6}	3.84×10^{5}	3.39×10^{5}	1.36×10^{5}	1.41×10^{5}
16	Glass Epoxy (GF) - 6225	3.34×10^{8}	*4.76×10^{7}	3.35×10^{6}	2.38×10^{5}	2.71×10^{5}	*1.37×10^{4}	*1.56×10^{4}
17	Glass Epoxy (GF) - 6225	3.57×10^{8}	1.67×10^{6}	5.56×10^{6}	1.11×10^{5}	*4.76×10^{6}	1.08×10^{5}	2.50×10^{5}
18	Glass Epoxy (GF) - 6225	2.50×10^{8}	1.79×10^{6}	2.33×10^{6}	1.45×10^{5}	2.64×10^{5}	*1.15×10^{4}	2.33×10^{5}
19	Glass Epoxy (GF) - 6225	1.54×10^{8}	1.39×10^{6}	3.70×10^{6}	1.39×10^{5}	2.27×10^{5}	3.00×10^{5}	2.26×10^{5}
20	Glass Epoxy (GF) - 6225	4.00×10^{8}	3.34×10^{6}	2.70×10^{6}	2.94×10^{5}	4.17×10^{5}	3.34×10^{5}	1.00×10^{5}
	Average Values	2.95×10^{8}	2.05×10^{6}	3.54×10^{6}	1.85×10^{5}	2.95×10^{5}	2.47×10^{5}	2.02×10^{5}

* - Not averaged in total.

TABLE XXIV (CONT)

INSULATION RESISTANCE TEST RESULTS OF TEST PATTERN 6225 (100 VOLTS D.C.)

Board No.	Laminate Base & Pattern Design No.	INSULATION RESISTANCE (In Megohms) AT 100 VOLTS D.C. APPLIED TO EACH BOARD						
		Initial Reading	First Day	Third Day	Fifth Day	Seventh Day	Ninth Day	Tenth Day
21	Glass Melamine (GM) - 6225	2.28×10^{7}	2.94×10^{6}	3.03×10^{5}	1.73×10^{5}	1.19×10^{4}	1.43×10^{4}	1.16×10^{4}
22	Glass Melamine (GM) - 6225	$*1.52 \times 10^{6}$	2.50×10^{6}	4.17×10^{5}	1.06×10^{5}	1.14×10^{4}	1.08×10^{4}	1.21×10^{4}
23	Glass Melamine (GM) - 6225	4.76×10^{7}	1.67×10^{6}	4.15×10^{5}	1.04×10^{5}	1.09×10^{4}	1.08×10^{4}	1.04×10^{4}
24	Glass Melamine (GM) - 6225	3.13×10^{7}	$*1.33 \times 10^{5}$	2.75×10^{5}	$*1.06 \times 10^{4}$	1.11×10^{4}	1.06×10^{4}	1.56×10^{4}
25	Glass Melamine (GM) - 6225	2.13×10^{7}	2.22×10^{6}	3.29×10^{5}	1.39×10^{5}	1.25×10^{4}	1.25×10^{4}	1.07×10^{4}
	Average Values	3.08×10^{7}	2.33×10^{6}	3.48×10^{5}	1.31×10^{5}	1.16×10^{4}	1.18×10^{4}	1.21×10^{4}
26	Glass Silicone (GS) - 6225	2.50×10^{7}	1.34×10^{7}	1.11×10^{5}	1.67×10^{5}	1.67×10^{5}	2.78×10^{5}	2.00×10^{5}
27	Glass Silicone (GS) - 6225	1.01×10^{7}	$*1.11 \times 10^{6}$	$*1.85 \times 10^{6}$	1.85×10^{5}	1.00×10^{5}	2.50×10^{5}	2.22×10^{5}
28	Glass Silicone (GS) - 6225	3.71×10^{7}	2.86×10^{7}	2.23×10^{5}	1.25×10^{5}	1.25×10^{5}	2.63×10^{5}	2.00×10^{5}
29	Glass Silicone (GS) - 6225	3.33×10^{7}	2.22×10^{7}	1.39×10^{5}	3.58×10^{5}	1.67×10^{5}	1.52×10^{5}	$*1.72 \times 10^{4}$
30	Glass Silicone (GS) - 6225	1.04×10^{7}	$*1.12 \times 10^{6}$	3.23×10^{5}	1.30×10^{5}	2.00×10^{5}	1.85×10^{5}	1.82×10^{5}
	Average Values	2.32×10^{7}	2.14×10^{7}	1.99×10^{5}	1.93×10^{5}	1.52×10^{5}	2.06×10^{5}	2.01×10^{5}

* - Not averaged in total.

TABLE XXV

INSULATION RESISTANCE TEST RESULTS OF TEST PATTERN 55110 (100 VOLTS D.C.)

Board No.	Laminate Base & Pattern Design No.	INSULATION RESISTANCE (In Megohms) AT 100 VOLTS D.C. APPLIED TO EACH BOARD						
		Initial Reading	First Day	Third Day	Fifth Day	Seventh Day	Ninth Day	Tenth Day
31	Paper Phenolic (PP) - 55110	1.09×10^7	1.43×10^7	1.67×10^7	5.56×10^6	*6.67×10^6	*8.34×10^6	*1.00×10^6
32	Paper Phenolic (PP) - 55110	1.12×10^7	1.54×10^7	*1.19×10^4	*2.84×10^5	5.00×10^5	3.03×10^5	3.34×10^5
33	Paper Phenolic (PP) - 55110	5.26×10^7	1.67×10^7	1.43×10^7	1.00×10^6	4.00×10^5	5.00×10^5	4.00×10^5
34	Paper Phenolic (PP) - 55110	2.13×10^7	6.67×10^7	*1.11×10^5	*2.78×10^3	5.00×10^5	1.67×10^5	*6.67×10^6
35	Paper Phenolic (PP) - 55110	5.03×10^7	1.64×10^7	1.67×10^7	2.00×10^6	4.55×10^5	*9.10×10^5	6.67×10^5
	Average Values	2.93×10^7	2.59×10^7	1.59×10^7	2.86×10^6	4.64×10^5	3.23×10^5	4.48×10^5
36	Glass Epoxy (GE) - 55110	4.55×10^7	1.67×10^7	1.28×10^5	1.56×10^5	2.86×10^5	5.72×10^5	*5.55×10^4
37	Glass Epoxy (GE) - 55110	2.22×10^7	1.54×10^7	2.00×10^5	*8.34×10^5	3.34×10^5	6.67×10^5	1.43×10^5
38	Glass Epoxy (GE) - 55110	1.67×10^7	1.85×10^7	1.05×10^5	*3.34×10^6	2.57×10^5	1.11×10^6	2.00×10^5
39	Glass Epoxy (GE) - 55110	1.85×10^7	1.33×10^7	2.22×10^5	1.32×10^5	2.22×10^5	4.76×10^5	4.00×10^5
40	Glass Epoxy (GE) - 55110	1.72×10^7	1.43×10^7	2.38×10^5	1.11×10^5	2.86×10^5	1.67×10^5	3.34×10^5
	Average Values	2.41×10^7	1.56×10^7	1.78×10^5	1.33×10^5	2.75×10^5	3.99×10^5	2.69×10^5
41	Glass Epoxy (GB) - 55110	*1.11×10^7	6.67×10^7	2.33×10^6	6.67×10^5	8.33×10^5	2.22×10^5	2.27×10^5
42	Glass Epoxy (GB) - 55110	8.33×10^8	*2.57×10^6	2.63×10^6	4.00×10^5	2.22×10^5	2.00×10^5	2.50×10^5
43	Glass Epoxy (GB) - 55110	5.00×10^8	6.67×10^7	3.03×10^6	8.33×10^5	3.33×10^5	*1.19×10^4	2.18×10^5
44	Glass Epoxy (GB) - 55110	1.00×10^8	2.22×10^7	2.13×10^6	2.57×10^5	6.67×10^5	1.06×10^5	3.34×10^5
45	Glass Epoxy (GB) - 55110	2.18×10^8	3.58×10^7	3.45×10^6	5.00×10^5	1.43×10^5	2.33×10^5	*1.67×10^4
	Average Values	4.13×10^8	4.78×10^7	2.71×10^6	5.32×10^5	4.40×10^5	1.90×10^5	2.58×10^5

* - Not averaged in total.

TABLE XXV (CONT)

INSULATION RESISTANCE TEST RESULTS OF TEST PATTERN 55110 (100 VOLTS D.C.)

Board No.	Laminate Base & Pattern Design No.	INSULATION RESISTANCE (In Megohms) AT 100 VOLTS D.C. APPLIED TO EACH BOARD Initial Reading	First Day	Third Day	Fifth Day	Seventh Day	Ninth Day	Tenth Day
46	Glass Epoxy (GF) - 55110	9.10×10^{8}	2.78×10^{7}	3.57×10^{6}	3.13×10^{5}	*1.61×10^{4}	*1.43×10^{4}	*1.09×10^{4}
47	Glass Epoxy (GF) - 55110	8.33×10^{8}	5.56×10^{7}	2.13×10^{6}	2.78×10^{5}	1.11×10^{5}	2.50×10^{5}	1.02×10^{5}
48	Glass Epoxy (GF) 55110	1.00×10^{8}	*1.61×10^{6}	5.27×10^{6}	2.13×10^{5}	2.63×10^{5}	2.18×10^{5}	2.36×10^{5}
49	Glass Epoxy (GF) - 55110	*1.25×10^{7}	2.78×10^{7}	3.45×10^{6}	2.38×10^{5}	3.13×10^{5}	*1.18×10^{4}	6.25×10^{5}
50	Glass Epoxy (GF) - 55110	1.00×10^{8}	3.12×10^{7}	3.34×10^{6}	3.03×10^{5}	3.34×10^{5}	2.04×10^{5}	3.34×10^{5}
	Average Values	4.86×10^{8}	3.56×10^{7}	3.56×10^{6}	2.69×10^{6}	2.56×10^{5}	2.24×10^{5}	3.24×10^{5}
51	Glass Melamine (GM) - 55110	2.27×10^{7}	2.94×10^{6}	3.03×10^{5}	1.73×10^{5}	1.19×10^{4}	1.43×10^{4}	1.16×10^{4}
52	Glass Melamine (GM) - 55110	1.52×10^{7}	2.50×10^{6}	4.17×10^{5}	1.06×10^{5}	1.14×10^{4}	1.08×10^{4}	1.22×10^{4}
53	Glass Melamine (GM) - 55110	4.77×10^{7}	1.67×10^{6}	4.45×10^{5}	*1.04×10^{4}	1.09×10^{4}	1.07×10^{4}	1.04×10^{4}
54	Glass Melamine (GM) - 55110	3.13×10^{7}	*1.34×10^{5}	2.75×10^{5}	1.06×10^{5}	1.11×10^{4}	1.06×10^{4}	1.56×10^{4}
55	Glass Melamine (GM) - 55110	2.13×10^{7}	2.22×10^{6}	3.29×10^{5}	1.39×10^{5}	1.25×10^{4}	1.25×10^{4}	1.12×10^{4}
	Average Values	2.77×10^{7}	2.33×10^{6}	3.54×10^{5}	1.31×10^{5}	1.16×10^{4}	1.18×10^{4}	1.21×10^{4}
56	Glass Silicone (GS) - 55110	1.14×10^{7}	1.85×10^{7}	*1.56×10^{4}	1.11×10^{6}	1.00×10^{5}	2.50×10^{5}	5.00×10^{5}
57	Glass Silicone (GS) - 55110	6.67×10^{7}	3.34×10^{7}	*1.22×10^{5}	*3.34×10^{4}	2.86×10^{5}	2.22×10^{6}	4.00×10^{5}
58	Glass Silicone (GS) - 55110	4.17×10^{7}	1.67×10^{7}	1.43×10^{6}	*2.18×10^{5}	2.38×10^{5}	4.17×10^{5}	1.18×10^{5}
59	Glass Silicone (GS) - 55110	5.30×10^{7}	1.54×10^{7}	3.33×10^{6}	*1.12×10^{4}	2.22×10^{5}	4.17×10^{5}	6.67×10^{5}
60	Glass Silicone (GS) - 55110	3.23×10^{7}	1.11×10^{7}	1.79×10^{6}	1.33×10^{6}	2.57×10^{5}	3.45×10^{5}	2.22×10^{5}
	Average Values	4.90×10^{7}	1.90×10^{7}	2.18×10^{6}	1.22×10^{6}	2.21×10^{5}	3.30×10^{5}	3.82×10^{5}

* - Not averaged in total.

TABLE XXVI

INSULATION RESISTANCE TEST RESULTS OF TEST COMMERCIAL COMB PATTERN (100 VOLTS D.C.)

Board No.	Laminate Base & Pattern Design No.	INSULATION RESISTANCE (In Megohms) AT 100 VOLTS D.C. APPLIED TO EACH BOARD						
		Initial Reading	First Day	Third Day	Fifth Day	Seventh Day	Ninth Day	Tenth Day
61	Paper Phenolic (PP) - Com.	2.22×10^{7}	1.33×10^{7}	2.22×10^{6}	3.13×10^{5}	*7.15×10^{4}	5.00×10^{5}	2.78×10^{5}
62	Paper Phenolic (PP) - Com.	6.25×10^{7}	1.45×10^{7}	1.85×10^{6}	1.19×10^{5}	*8.34×10^{4}	1.82×10^{5}	2.22×10^{5}
63	Paper Phenolic (PP) - Com.	1.75×10^{7}	1.54×10^{7}	1.19×10^{6}	*8.34×10^{6}	1.06×10^{5}	*1.67×10^{6}	3.34×10^{5}
64	Paper Phenolic (PP) - Com.	1.04×10^{7}	1.39×10^{7}	*1.00×10^{5}	3.13×10^{5}	2.86×10^{5}	3.34×10^{5}	3.03×10^{5}
65	Paper Phenolic (PP) - Com.	*1.16×10^{6}	1.11×10^{7}	1.60×10^{6}	1.72×10^{5}	1.67×10^{5}	4.17×10^{5}	4.17×10^{5}
	Average Values	2.82×10^{7}	1.36×10^{7}	1.72×10^{6}	2.29×10^{5}	1.86×10^{5}	3.56×10^{5}	3.11×10^{5}
66	Glass Epoxy (GE) - Com.	4.00×10^{7}	1.11×10^{7}	1.03×10^{6}	*8.34×10^{4}	*8.70×10^{4}	1.00×10^{5}	4.00×10^{5}
67	Glass Epoxy (GE) - Com.	2.04×10^{7}	1.67×10^{7}	*2.27×10^{4}	*6.57×10^{5}	1.05×10^{5}	2.50×10^{5}	3.33×10^{5}
68	Glass Epoxy (GE) - Com.	1.62×10^{7}	*6.67×10^{6}	1.02×10^{6}	1.56×10^{5}	1.35×10^{5}	*7.15×10^{4}	3.03×10^{5}
69	Glass Epoxy (GE) - Com.	1.33×10^{7}	*7.14×10^{6}	1.56×10^{6}	2.57×10^{5}	1.00×10^{5}	1.00×10^{5}	4.77×10^{5}
70	Glass Epoxy (GE) - Com.	6.67×10^{7}	1.11×10^{7}	2.30×10^{6}	3.03×10^{5}	2.94×10^{5}	1.25×10^{5}	2.00×10^{5}
	Average Values	3.13×10^{7}	1.29×10^{7}	1.48×10^{6}	2.39×10^{5}	2.11×10^{5}	1.44×10^{5}	3.43×10^{5}
71	Glass Epoxy (GB) - Com.	1.11×10^{8}	6.67×10^{7}	2.33×10^{6}	6.67×10^{5}	8.34×10^{5}	2.22×10^{5}	2.28×10^{5}
72	Glass Epoxy (GB) - Com.	8.33×10^{8}	*2.57×10^{6}	2.63×10^{6}	4.00×10^{5}	2.22×10^{5}	2.00×10^{5}	2.50×10^{5}
73	Glass Epoxy (GB) - Com.	5.00×10^{8}	6.67×10^{7}	3.03×10^{6}	8.34×10^{5}	3.34×10^{5}	1.19×10^{5}	2.18×10^{5}
74	Glass Epoxy (GB) - Com.	1.00×10^{8}	2.22×10^{7}	2.13×10^{6}	2.57×10^{5}	6.67×10^{5}	1.06×10^{5}	3.34×10^{5}
75	Glass Epoxy (GB) - Com.	2.18×10^{8}	5.00×10^{7}	3.57×10^{6}	5.00×10^{5}	1.43×10^{5}	2.32×10^{5}	1.67×10^{5}
	Average Values	3.52×10^{8}	5.14×10^{7}	2.74×10^{6}	5.31×10^{5}	4.40×10^{5}	1.76×10^{5}	2.39×10^{5}

* - Not averaged in total.

TABLE XXVI (CONT)

INSULATION RESISTANCE TEST RESULTS OF TEST COMMERCIAL COMB PATTERN (100 VOLTS D.C.)

Board No.	Laminate Base & Pattern Design No.	INSULATION RESISTANCE (In Megohms) AT 100 VOLTS D.C. APPLIED TO EACH BOARD						
		Initial Reading	First Day	Third Day	Fifth Day	Seventh Day	Ninth Day	Tenth Day
76	Glass Epoxy (GF) - Com.	3.34×10^{8}	*1.43×10^{6}	3.03×10^{6}	1.79×10^{5}	2.08×10^{5}	2.18×10^{5}	2.09×10^{5}
77	Glass Epoxy (GF) - Com.	*1.82×10^{7}	2.08×10^{7}	2.27×10^{6}	*1.85×10^{4}	2.50×10^{5}	2.04×10^{5}	2.18×10^{5}
78	Glass Epoxy (GF) - Com.	2.00×10^{8}	2.44×10^{7}	2.00×10^{6}	2.08×10^{5}	2.38×10^{5}	2.08×10^{5}	1.00×10^{5}
79	Glass Epoxy (GF) - Com.	5.00×10^{8}	2.55×10^{7}	2.33×10^{6}	2.78×10^{5}	*1.79×10^{4}	2.13×10^{5}	2.17×10^{5}
80	Glass Epoxy (GF) - Com.	2.22×10^{8}	2.78×10^{7}	3.58×10^{6}	3.12×10^{5}	2.73×10^{5}	*1.85×10^{4}	*1.11×10^{4}
	Average Values	3.14×10^{8}	2.46×10^{7}	2.65×10^{6}	3.77×10^{5}	2.44×10^{5}	2.11×10^{5}	1.86×10^{5}
81	Glass Melamine (GM) - Com.	3.34×10^{7}	2.22×10^{6}	4.35×10^{5}	2.38×10^{5}	1.85×10^{4}	1.03×10^{4}	1.43×10^{4}
82	Glass Melamine (GM) - Com.	*1.35×10^{6}	1.67×10^{6}	4.17×10^{5}	*1.05×10^{4}	4.17×10^{4}	1.75×10^{4}	2.94×10^{4}
83	Glass Melamine (GM) - Com.	1.28×10^{7}	1.57×10^{6}	2.94×10^{5}	5.00×10^{5}	5.56×10^{4}	1.69×10^{4}	1.18×10^{4}
84	Glass Melamine (GM) - Com.	2.27×10^{7}	1.73×10^{6}	2.33×10^{5}	1.02×10^{5}	3.12×10^{4}	2.38×10^{4}	1.67×10^{4}
85	Glass Melamine (GM) - Com.	1.22×10^{7}	1.67×10^{6}	3.03×10^{5}	1.28×10^{5}	1.11×10^{4}	1.67×10^{4}	2.50×10^{4}
	Average Values	2.03×10^{7}	1.78×10^{6}	3.37×10^{5}	2.42×10^{5}	3.17×10^{4}	1.70×10^{4}	1.94×10^{4}

* - Not averaged in total.

TABLE XXVI (CONT)

INSULATION RESISTANCE TEST RESULTS OF TEST COMMERCIAL COMB PATTERN (100 VOLTS D.C.)

Board No.	Laminate Base & Pattern Design No.	INSULATION RESISTANCE (In Megohms) AT 100 VOLTS D.C. APPLIED TO EACH BOARD						
		Initial Reading	First Day	Third Day	Fifth Day	Seventh Day	Ninth Day	Tenth Day
86	Glass Silicone (GS) - Com.	$1.03x10^7$	$2.38x10^7$	$1.13x10^5$	$1.67x10^5$	$*8.34x10^4$	$1.76x10^5$	$1.67x10^5$
87	Glass Silicone (GS) - Com.	$5.55x10^7$	$1.85x10^7$	$3.12x10^5$	$1.51x10^5$	$1.67x10^5$	$1.52x10^5$	$2.63x10^5$
88	Glass Silicone (GS) - Com.	$1.35x10^7$	$1.33x10^7$	$1.37x10^5$	$3.34x10^5$	$1.85x10^5$	$1.33x10^5$	$1.11x10^5$
89	Glass Silicone (GS) - Com.	$5.88x10^7$	$3.34x10^7$	$1.92x10^5$	$1.00x10^6$	$2.57x10^5$	$1.67x10^5$	$1.28x10^5$
90	Glass Silicone (GS) - Com.	$1.39x10^7$	$1.25x10^7$	$2.38x10^5$	$1.39x10^5$	$1.67x10^5$	$2.78x10^5$	$4.17x10^5$
	Average Values	$3.04x10^7$	$2.03x10^7$	$1.99x10^5$	$1.98x10^5$	$1.94x10^5$	$1.81x10^5$	$2.17x10^5$

* - Not averaged in total.

TABLE XXVII

INSULATION RESISTANCE TEST RESULTS OF TEST PATTERN 6225 (500 VOLTS D.C.)

Board No.	Laminate Base & Pattern Design No.	INSULATION RESISTANCE (In Megohms) AT 500 VOLTS D.C. APPLIED TO EACH BOARD Initial Reading	First Day	Third Day	Fifth Day	Seventh Day	Ninth Day	Tenth Day
1	Paper Phenolic (PP)-6225	1.47×10^{8}	7.15×10^{7}	*5.55×10^{4}	1.78×10^{5}	*1.25×10^{5}	*1.19×10^{5}	5.22×10^{5}
2	Paper Phenolic (PP)-6225	1.16×10^{8}	8.34×10^{7}	1.56×10^{6}	2.08×10^{5}	*1.04×10^{5}	5.55×10^{5}	7.15×10^{5}
3	Paper Phenolic (PP)-6225	3.12×10^{8}	3.35×10^{7}	1.28×10^{6}	*1.25×10^{3}	7.15×10^{5}	6.76×10^{5}	5.88×10^{5}
4	Paper Phenolic (PP)-6225	1.56×10^{8}	8.34×10^{7}	1.28×10^{6}	3.12×10^{5}	6.10×10^{5}	*1.25×10^{5}	7.35×10^{5}
5	Paper Phenolic (PP)-6225	2.00×10^{8}	8.34×10^{7}	2.45×10^{6}	2.63×10^{5}	6.33×10^{5}	6.58×10^{5}	*1.57×10^{4}
	Average Values	1.86×10^{8}	7.10×10^{7}	1.64×10^{6}	2.40×10^{5}	6.53×10^{5}	6.28×10^{5}	6.40×10^{5}
6	Glass Epoxy (GE) - 6225	3.57×10^{8}	1.11×10^{7}	*8.07×10^{7}	*1.78×10^{5}	*8.34×10^{5}	*7.25×10^{5}	9.80×10^{5}
7	Glass Epoxy (GE) - 6225	2.78×10^{8}	*7.15×10^{8}	1.25×10^{5}	6.76×10^{5}	1.67×10^{5}	1.39×10^{5}	7.25×10^{5}
8	Glass Epoxy (GE) - 6225	2.08×10^{8}	1.25×10^{7}	*8.33×10^{6}	7.82×10^{5}	*6.67×10^{5}	1.19×10^{5}	6.67×10^{5}
9	Glass Epoxy (GE) - 6225	5.00×10^{8}	1.67×10^{7}	1.39×10^{5}	5.82×10^{5}	1.25×10^{5}	1.00×10^{5}	5.56×10^{5}
10	Glass Epoxy (GE) - 6225	4.55×10^{8}	1.11×10^{7}	1.19×10^{5}	3.33×10^{5}	1.47×10^{5}	2.27×10^{5}	*5.56×10^{2}
	Average Values	3.60×10^{8}	1.28×10^{7}	1.28×10^{5}	5.93×10^{5}	1.46×10^{5}	1.46×10^{5}	7.31×10^{5}
11	Glass Epoxy (GB) - 6225	2.17×10^{8}	1.39×10^{7}	1.51×10^{6}	1.11×10^{5}	*8.34×10^{5}	1.14×10^{5}	*8.94×10^{5}
12	Glass Epoxy (GB) - 6225	1.47×10^{8}	1.28×10^{7}	1.78×10^{6}	1.67×10^{5}	1.25×10^{5}	2.86×10^{5}	*6.76×10^{5}
13	Glass Epoxy (GB) - 6225	1.67×10^{8}	*5.56×10^{6}	1.35×10^{6}	*8.34×10^{5}	1.67×10^{5}	1.52×10^{5}	1.19×10^{5}
14	Glass Epoxy (GB) - 6225	1.32×10^{8}	2.38×10^{7}	1.25×10^{6}	3.33×10^{5}	1.39×10^{5}	1.25×10^{5}	1.11×10^{5}
15	Glass Epoxy (GB) - 6225	*7.58×10^{7}	1.19×10^{7}	1.16×10^{6}	5.56×10^{5}	1.47×10^{5}	1.28×10^{5}	1.09×10^{5}
	Average Values	1.66×10^{8}	1.56×10^{7}	1.41×10^{6}	2.92×10^{5}	1.45×10^{5}	1.61×10^{5}	1.13×10^{5}

* - Not averaged in total.

TABLE XXVII (CONT)

INSULATION RESISTANCE TEST RESULTS OF TEST PATTERN 6225 (500 VOLTS D.C.)

Board No.	Laminate Base & Pattern Design No.	INSULATION RESISTANCE (In Megohms) AT 500 VOLTS D.C. APPLIED TO EACH BOARD						
		Initial Reading	First Day	Third Day	Fifth Day	Seventh Day	Ninth Day	Tenth Day
16	Glass Epoxy (GF)-6225	$*8.34x10^7$	$5.56x10^7$	$1.39x10^6$	$*5.56x10^5$	$*7.15x10^5$	$1.00x10^5$	$1.17x10^5$
17	Glass Epoxy (GF)-6225	$1.09x10^8$	$*8.07x10^7$	$1.72x10^6$	$2.08x10^5$	$1.92x10^5$	$1.47x10^5$	$1.00x10^5$
18	Glass Epoxy (GF)-6225	$1.00x10^8$	$1.32x10^7$	$1.52x10^6$	$1.82x10^5$	$1.19x10^5$	$1.52x10^5$	$1.04x10^5$
19	Glass Epoxy (GF)-6225	$1.28x10^8$	$1.09x10^7$	$1.35x10^6$	$2.00x10^5$	$1.47x10^5$	$1.32x10^5$	$1.19x10^5$
20	Glass Epoxy (GF)-6225	$1.19x10^8$	$1.22x10^7$	$1.43x10^6$	$1.39x10^5$	$1.79x10^5$	$1.22x10^5$	$1.04x10^5$
	Average Values	$1.14x10^8$	$2.29x10^7$	$1.48x10^6$	$1.82x10^5$	$1.59x10^5$	$1.31x10^5$	$1.09x10^5$
21	Glass Melamine (GM)-6225	$*9.26x10^7$	$1.67x10^6$	$*5.00x10^5$	$2.27x10^5$	$2.27x10^4$	$8.34x10^4$	$1.00x10^4$
22	Glass Melamine (GM)-6225	$*6.76x10^7$	$1.19x10^6$	$2.72x10^5$	$1.67x10^5$	$2.78x10^4$	$7.82x10^4$	$*1.00x10^5$
23	Glass Melamine (GM)-6225	$1.67x10^7$	$*6.67x10^6$	$1.76x10^5$	$2.27x10^5$	$1.39x10^4$	$9.26x10^4$	$8.34x10^4$
24	Glass Melamine (GM)-6225	$1.32x10^7$	$1.92x10^6$	$1.68x10^5$	$1.09x10^5$	$*6.58x10^4$	$8.48x10^4$	$7.15x10^4$
25	Glass Melamine (GM)-6225	$1.67x10^7$	$*6.62x10^6$	$1.57x10^5$	$1.00x10^5$	$*8.07x10^4$	$7.15x10^4$	$2.27x10^4$
	Average Values	$1.55x10^7$	$1.59x10^6$	$1.94x10^5$	$1.66x10^5$	$2.14x10^4$	$8.22x10^4$	$4.68x10^4$
26	Glass Silicone (GS)-6225	$1.06x10^8$	$6.25x10^7$	$1.67x10^6$	$*5.62x10^3$	$1.00x10^5$	$6.58x10^4$	$*1.67x10^5$
27	Glass Silicone (GS)-6225	$1.85x10^8$	$7.70x10^7$	$1.19x10^6$	$1.19x10^5$	$*8.34x10^4$	$5.56x10^4$	$1.31x10^4$
28	Glass Silicone (GS)-6225	$2.50x10^8$	$*2.00x10^7$	$1.39x10^6$	$*1.47x10^5$	$*6.25x10^4$	$5.56x10^4$	$7.58x10^4$
29	Glass Silicone (GS)-6225	$1.00x10^8$	$7.25x10^7$	$*1.25x10^6$	$*7.15x10^4$	$1.56x10^5$	$*1.66x10^4$	$5.33x10^4$
30	Glass Silicone (GS)-6225	$1.28x10^8$	$5.56x10^7$	$*6.67x10^5$	$3.12x10^5$	$1.04x10^5$	$8.33x10^4$	$5.56x10^4$
	Average Values	$1.54x10^8$	$6.68x10^7$	$1.37x10^6$	$1.93x10^5$	$1.20x10^5$	$6.52x10^4$	$6.15x10^4$

* - Not averaged in total.

TABLE XXVIII

INSULATION RESISTANCE TEST RESULTS OF TEST PATTERN 55110 (500 VOLTS D.C.)

Board No.	Laminate Base & Pattern Design No.	INSULATION RESISTANCE (In Megohms) AT 500 VOLTS D.C. APPLIED TO EACH BOARD						
		Initial Reading	First Day	Third Day	Fifth Day	Seventh Day	Ninth Day	Tenth Day
31	Paper Phenolic (PP)-55110	1.25×10^8	5.56×10^7	1.56×10^6	$*8.34 \times 10^5$	7.35×10^5	2.78×10^5	2.50×10^5
32	Paper Phenolic (PP)-55110	1.43×10^8	1.13×10^7	$*1.07 \times 10^2$	2.50×10^5	1.25×10^5	6.25×10^5	1.67×10^5
33	Paper Phenolic (PP)-55110	2.27×10^8	1.11×10^7	1.00×10^6	1.67×10^5	8.34×10^5	4.55×10^5	1.67×10^5
34	Paper Phenolic (PP)-55110	1.22×10^8	6.67×10^7	1.39×10^6	1.11×10^5	8.34×10^5	2.08×10^5	$*9.27 \times 10^5$
35	Paper Phenolic (PP)-55110	$*6.25 \times 10^7$	3.34×10^7	1.25×10^6	5.56×10^5	1.19×10^5	2.38×10^5	1.51×10^5
	Average Values	1.54×10^8	3.56×10^7	1.30×10^6	2.72×10^5	5.30×10^5	3.61×10^5	1.84×10^5
36	Glass Epoxy (GE)-55110	$*6.25 \times 10^8$	1.67×10^8	7.58×10^5	4.16×10^6	1.67×10^5	5.44×10^5	$*8.93 \times 10^4$
37	Glass Epoxy (GE)-55110	2.28×10^8	1.67×10^8	5.21×10^5	$*1.67 \times 10^6$	5.95×10^5	5.56×10^5	7.35×10^5
38	Glass Epoxy (GE)-55110	2.63×10^8	3.33×10^8	$*1.09 \times 10^2$	5.00×10^5	5.56×10^5	$*8.34 \times 10^4$	5.95×10^5
39	Glass Epoxy (GE)-55110	2.08×10^8	1.67×10^8	7.95×10^5	$*1.67 \times 10^2$	$*1.04 \times 10^4$	5.56×10^5	1.11×10^5
40	Glass Epoxy (GE)-55110	2.08×10^8	1.11×10^8	6.42×10^5	5.56×10^5	2.38×10^5	2.78×10^5	6.42×10^5
	Average Values	2.26×10^8	1.89×10^8	6.78×10^5	4.92×10^5	3.89×10^5	4.84×10^5	5.21×10^5
41	Glass Epoxy (GB)-55110	1.47×10^8	1.28×10^7	1.32×10^6	5.82×10^5	1.79×10^5	1.35×10^5	1.25×10^5
42	Glass Epoxy (GB)-55110	$*7.82 \times 10^8$	$*6.67 \times 10^7$	1.16×10^6	8.34×10^5	1.25×10^5	1.33×10^5	1.14×10^5
43	Glass Epoxy (GB)-55110	2.17×10^8	1.19×10^7	1.09×10^6	7.70×10^5	1.72×10^5	1.32×10^5	1.09×10^5
44	Glass Epoxy (GB)-55110	1.19×10^8	$*6.95 \times 10^7$	1.52×10^6	7.25×10^5	3.57×10^5	1.72×10^5	1.04×10^5
45	Glass Epoxy (GB)-55110	1.25×10^8	1.67×10^7	1.85×10^6	5.00×10^5	1.92×10^5	1.52×10^5	1.19×10^5
	Average Values	1.52×10^8	1.38×10^7	1.39×10^6	6.83×10^5	2.05×10^5	1.44×10^5	1.14×10^5

* - Not averaged in total.

TABLE XXVIII (CONT)

INSULATION RESISTANCE TEST RESULTS OF TEST PATTERN 55110 (500 VOLTS D.C.)

Board No.	Laminate Base & Pattern Design No.	INSULATION RESISTANCE (In Megohms) AT 500 VOLTS D.C. APPLIED TO EACH BOARD						
		Initial Reading	First Day	Third Day	Fifth Day	Seventh Day	Ninth Day	Tenth Day
46	Glass Epoxy (GF)-55110	*8.94×10^{8}	6.33×10^{7}	1.52×10^{6}	*8.07×10^{5}	1.39×10^{5}	1.00×10^{5}	1.14×10^{5}
47	Glass Epoxy (GF)-55110	*9.26×10^{8}	6.76×10^{7}	1.72×10^{6}	*1.79×10^{5}	1.67×10^{5}	1.25×10^{5}	1.19×10^{5}
48	Glass Epoxy (GF)-55110	1.00×10^{8}	7.05×10^{7}	1.47×10^{6}	7.15×10^{5}	2.27×10^{5}	1.52×10^{5}	1.11×10^{5}
49	Glass Epoxy (GF)-55110	1.92×10^{8}	*1.28×10^{7}	1.67×10^{6}	*1.00×10^{5}	1.92×10^{5}	1.32×10^{5}	1.00×10^{5}
50	Glass Epoxy (GF)-55110	2.50×10^{8}	*1.11×10^{7}	1.35×10^{6}	7.35×10^{5}	1.79×10^{5}	1.47×10^{5}	1.14×10^{5}
	Average Values	1.80×10^{8}	6.71×10^{7}	1.54×10^{6}	7.52×10^{5}	1.80×10^{5}	1.31×10^{5}	1.12×10^{5}
51	Glass Melamine (GM)-55110	1.67×10^{7}	7.82×10^{6}	5.00×10^{5}	1.67×10^{5}	1.67×10^{4}	*1.33×10^{4}	*1.14×10^{4}
52	Glass Melamine (GM)-55110	1.04×10^{7}	9.62×10^{6}	3.58×10^{5}	1.80×10^{5}	8.34×10^{4}	6.76×10^{4}	5.95×10^{4}
53	Glass Melamine (GM)-55110	1.39×10^{7}	5.44×10^{6}	2.94×10^{5}	2.50×10^{5}	1.11×10^{4}	9.09×10^{4}	8.07×10^{4}
54	Glass Melamine (GM)-55110	1.67×10^{7}	6.76×10^{6}	3.12×10^{5}	1.82×10^{5}	7.82×10^{4}	7.15×10^{4}	7.35×10^{4}
55	Glass Melamine (GM)-55110	1.67×10^{7}	$6.76. 10^{6}$	3.12×10^{5}	1.82×10^{5}	7.82×10^{4}	7.15×10^{4}	7.35×10^{4}
	Average Values	- - - - -	- - - - -	- - - - -	- - - - -	- - - - -	- - - - -	- - - - -
56	Glass Silicone (GS)-55110	2.94×10^{8}	8.34×10^{7}	1.25×10^{5}	*1.67×10^{6}	1.85×10^{4}	3.34×10^{4}	1.43×10^{4}
57	Glass Silicone (GS)-55110	2.08×10^{8}	*1.67×10^{6}	1.00×10^{5}	*1.11×10^{3}	1.28×10^{4}	1.28×10^{4}	1.11×10^{4}
58	Glass Silicone (GS)-55110	5.56×10^{8}	*2.78×10^{7}	1.25×10^{5}	7.81×10^{5}	3.57×10^{4}	4.16×10^{4}	1.00×10^{4}
59	Glass Silicone (GS)-55110	*9.26×10^{7}	5.56×10^{7}	*8.34×10^{6}	5.00×10^{5}	*9.82×10^{4}	3.12×10^{4}	3.33×10^{4}
60	Glass Silicone (GS)-55110	1.19×10^{8}	8.34×10^{7}	1.04×10^{5}	8.34×10^{5}	*9.26×10^{4}	1.11×10^{4}	1.32×10^{4}
	Average Values	2.94×10^{8}	7.42×10^{7}	1.13×10^{5}	7.05×10^{5}	2.23×10^{4}	2.61×10^{4}	1.64×10^{4}

* - Not averaged in total.
1 - Specimen damaged (Not Tested)

TABLE XXIX

INSULATION RESISTANCE TEST RESULTS OF TEST-COMMERCIAL COMB PATTERN (500 VOLTS D.C.)

Board No.	Laminate Base & Pattern Design No.	INSULATION RESISTANCE (In Megohms) AT 500 VOLTS D.C. APPLIED TO EACH BOARD Initial Reading	First Day	Third Day	Fifth Day	Seventh Day	Ninth Day	Tenth Day
61	Paper Phenolic (PP) - Com.	1.56×10^8	8.63×10^7	*8.93×10^5	3.57×10^5	1.00×10^5	1.85×10^5	*8.34×10^5
62	Paper Phenolic (PP) - Com.	*8.63×10^8	*2.78×10^8	1.09×10^6	*6.25×10^5	2.50×10^5	*5.95×10^5	1.39×10^5
63	Paper Phenolic (PP) - Com.	1.43×10^8	*1.00×10^8	1.39×10^6	2.50×10^5	1.67×10^5	2.38×10^5	1.56×10^5
64	Paper Phenolic (PP) - Com.	2.18×10^8	8.34×10^7	*7.25×10^6	3.85×10^5	1.00×10^5	1.51×10^5	*7.15×10^4
65	Paper Phenolic (PP) - Com.	1.67×10^8	8.33×10^7	1.31×10^6	1.31×10^5	*8.33×10^5	1.56×10^5	1.56×10^5
	Average Values	1.71×10^8	8.43×10^7	1.26×10^6	2.81×10^5	1.54×10^5	1.83×10^5	1.50×10^5
66	Glass Epoxy (GE) - Com.	2.08×10^8	1.67×10^7	1.28×10^5	5.00×10^5	5.56×10^5	*2.08×10^4	5.56×10^5
67	Glass Epoxy (GE) - Com.	1.67×10^8	*1.11×10^8	7.35×10^5	2.27×10^5	1.09×10^5	5.56×10^5	1.25×10^5
68	Glass Epoxy (GE) - Com.	1.11×10^8	7.15×10^7	6.76×10^5	1.00×10^5	1.39×10^5	1.04×10^5	1.04×10^5
69	Glass Epoxy (GE) - Com.	1.04×10^8	8.34×10^7	*9.26×10^4	8.34×10^5	1.47×10^5	1.00×10^5	1.04×10^5
70	Glass Epoxy (GE) - Com.	*8.34×10^7	6.67×10^7	1.19×10^5	5.00×10^5	2.08×10^5	1.56×10^5	1.00×10^5
	Average Values	1.48×10^8	5.97×10^7	4.15×10^5	4.33×10^5	2.32×10^5	2.29×10^5	1.98×10^5
71	Glass Epoxy (GB) - Com.	2.08×10^8	2.08×10^7	1.79×10^6	*6.25×10^5	2.50×10^5	1.43×10^5	1.25×10^5
72	Glass Epoxy (GB) - Com.	2.50×10^8	1.25×10^7	1.61×10^6	3.12×10^5	2.50×10^5	1.67×10^5	1.25×10^5
73	Glass Epoxy (GB) - Com.	1.11×10^8	1.56×10^7	1.35×10^6	5.00×10^5	1.92×10^5	1.28×10^5	1.25×10^5
74	Glass Epoxy (GB) - Com.	1.25×10^8	1.00×10^7	2.50×10^6	1.72×10^5	1.39×10^5	1.32×10^5	1.19×10^5
75	Glass Epoxy (GB) - Com.	3.57×10^8	1.72×10^7	1.92×10^6	3.57×10^5	1.67×10^5	1.25×10^5	1.04×10^5
	Average Values	2.11×10^8	1.52×10^7	1.84×10^6	3.36×10^5	2.00×10^5	1.39×10^5	1.20×10^5

* - Not averaged in total.

TABLE XXIX (CONT)

INSULATION RESISTANCE TEST RESULTS OF TEST COMMERCIAL COMB PATTERN (500 VOLTS D.C.)

Board No.	Laminate Base & Pattern Design No.	INSULATION RESISTANCE (In Megohms) AT 500 VOLTS D.C. APPLIED TO EACH BOARD						
		Initial Reading	First Day	Third Day	Fifth Day	Seventh Day	Ninth Day	Tenth Day
76	Glass Epoxy (GF)-Com.	1.19×10^8	7.57×10^7	1.61×10^6	3.57×10^5	1.79×10^5	1.25×10^5	1.09×10^5
77	Glass Epoxy (GF)-Com.	1.67×10^8	8.06×10^7	1.16×10^6	3.12×10^5	2.08×10^5	1.92×10^5	1.14×10^5
78	Glass Epoxy (GF)-Com.	1.47×10^8	$^*2.27 \times 10^7$	1.35×10^6	3.57×10^5	2.27×10^5	1.28×10^5	1.22×10^5
79	Glass Epoxy (GF)-Com.	3.12×10^8	6.42×10^7	1.19×10^6	1.47×10^5	1.67×10^5	1.47×10^5	1.04×10^5
80	Glass Epoxy (GF)-Com.	1.75×10^8	8.34×10^7	1.43×10^6	5.10×10^5	1.67×10^5	1.47×10^5	1.14×10^5
	Average Values	1.84×10^8	7.60×10^7	1.35×10^6	3.37×10^5	1.89×10^5	1.45×10^5	1.12×10^5
81	Glass Melamine (GM)-Com.	1.11×10^7	9.26×10^6	7.15×10^5	3.12×10^5	1.92×10^4	$^*1.25 \times 10^4$	8.34×10^4
82	Glass Melamine (GM)-Com.	1.32×10^7	$^*1.14 \times 10^6$	6.67×10^5	5.27×10^5	1.32×10^4	8.62×10^4	8.06×10^4
83	Glass Melamine (GM)-Com.	1.67×10^7	$^*2.78 \times 10^6$	5.95×10^5	2.50×10^5	1.56×10^4	8.55×10^4	8.06×10^4
84	Glass Melamine (GM)-Com.	1.25×10^7	7.58×10^6	6.42×10^5	1.92×10^5	1.56×10^4	6.94×10^4	6.10×10^4
85	Glass Melamine (GM)-Com.	1.04×10^7	9.26×10^6	8.34×10^5	4.17×10^5	2.78×10^4	9.10×10^4	7.82×10^4
	Average Values	1.28×10^7	8.70×10^6	6.91×10^5	3.40×10^5	1.83×10^4	8.30×10^4	7.68×10^4
86	Glass Silicone (GS)-Com.	4.16×10^8	$^*1.43 \times 10^8$	7.82×10^5	1.02×10^5	6.10×10^4	5.82×10^4	8.34×10^4
87	Glass Silicone (GS)-Com.	1.51×10^8	1.25×10^7	1.19×10^5	$^*5.10 \times 10^5$	$^*1.19 \times 10^5$	8.34×10^4	5.56×10^4
88	Glass Silicone (GS)-Com.	1.78×10^8	8.34×10^7	1.56×10^5	1.72×10^5	2.50×10^4	6.95×10^4	5.58×10^4
89	Glass Silicone (GS)-Com.	2.64×10^8	1.00×10^7	$^*5.16 \times 10^2$	5.56×10^5	7.82×10^4	$^*1.09 \times 10^5$	7.15×10^4
90	Glass Silicone (GS)-Com.	2.08×10^8	8.34×10^7	1.09×10^5	5.11×10^5	1.92×10^4	1.67×10^4	1.39×10^4
	Average Values	2.08×10^8	4.73×10^7	2.92×10^5	2.69×10^5	4.58×10^4	5.69×10^4	5.61×10^4

- Not averaged in total.

measurements were taken on the comb patterns at both 100 volts and 500 volts DC. Figures 44 through 46 show the curves for insulation resistance versus time (measured at 100 volts DC) for test patterns 6225, 55110 and com. The three base laminates on which test patterns were made, were general purpose glass epoxy (GE), temperature resistant glass epoxy (GB), and flame retardant glass epoxy (GF). The curves in Figures 44 through 46 are identified according to laminate type. Comparing these curves in Figures 44, 45 and 46, the insulation resistance of all three test patterns (measured at 100 volts DC) on glass epoxy (GE) had an initial insulation resistance lower than either of glass epoxy types GB and GF. The final insulation resistance readings, at the end of ten days humidity cycling, of all three glass epoxy types were approximately the same 2 x 10^5 megohms.

Figures 47 through 49 show insulation resistance versus time (measured at 100 volts DC) for test patterns 6225, 55110 and commercial comb pattern on paper phenolic (PP), glass melamine (GM) and glass silicone (GS) base type laminates. The most significant difference in Figures 47, 48 and 49 is that glass melamine has a lower insulation resistance at the end of the 10 day humidity cycling than either of the paper phenolic or glass silicone laminates. This value was 1.00 x 10^4 megohms compared to 2.00 x 10^5 megohms for glass epoxy types GE, GB and GF, paper phenolic and glass silicone.

Figures 50 through 52 show curves for insulation resistance versus time (measured at 500 volts DC) for same type of test patterns on base laminates as in Figures 44 through 46. There was a larger variation during the 10 day humidity cycling of insulation resistance readings at 500 volts than at 100 volts for the three types of glass epoxy laminates.

The final resistance readings (after 10 day humidity cycling) of all three test patterns onthe glass epoxy base laminates (types GE, GB and GF) varied more widely when measured at 500 volts than at 100 volts.

Figures 53 through 55 show insulation resistance versus time (measured at 5 0 volts) of the same insulation test patterns as in Figures 44 through 52 but on base laminates of paper phenolic, glass melamine and glass silicone. Comparing these resistance curves it can be seen the paper phenolic base laminate gives a higher insulation resistance value at the end of the ten day cycling than either the glass melamine or silicone laminates, see table below:

Laminate Type	Insulation Resistance (Megohms)
Paper Phenolic (PP)	313,000
Glass Melamine (GM) and Glass Silicone (GS)	48,300

Figure 56 shows the test patterns that were used for measuring insulation resistance on the various laminated base materials.

To evaluate the test pattern laid out in MIL-P-55110 more completely, a number of readings were made using a modified version of this pattern, made symmetrical by providing the same pad and conductor configuration at each end of the pattern. Subsequently, comparative samples made in accordance with the test pattern were cycled for ten days.

The test results from these boards are tabulated below. Comparison with the 55110 results tabulated in Table XXV and XXVIII show close enough correlation to allow the results

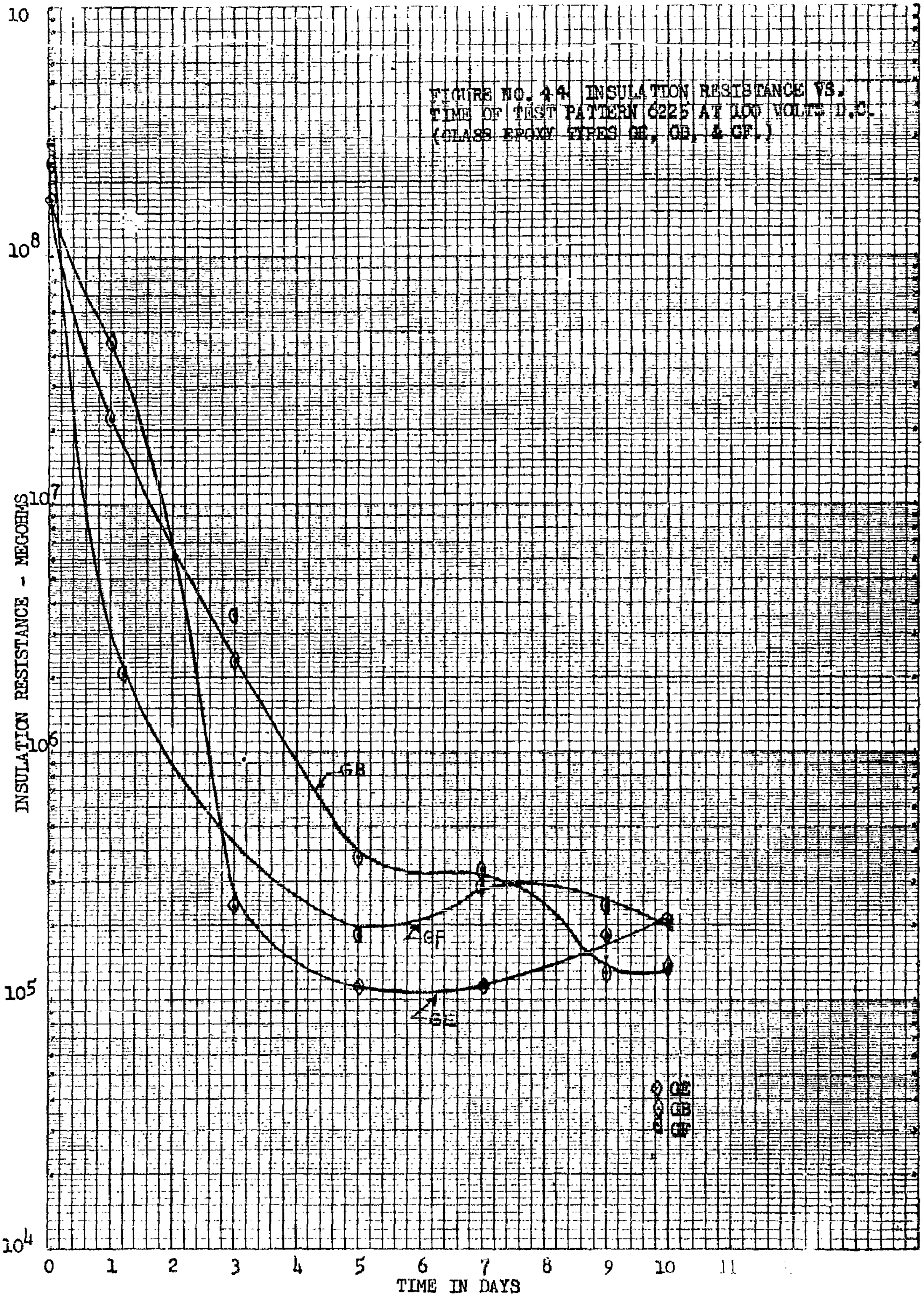


FIGURE NO. 44 INSULATION RESISTANCE VS. TIME OF TEST PATTERN 6225 AT 100 VOLTS D.C. (GLASS EPOXY TYPES GE, GB, & GF.)
INSULATION RESISTANCE - MEGOHMS
10
10^8
10^7
10^6
10^5
10^4
0
1
2
3
4
5
6
7
8
9
10
11
TIME IN DAYS
GB
GF
GE
GE
GB
GF

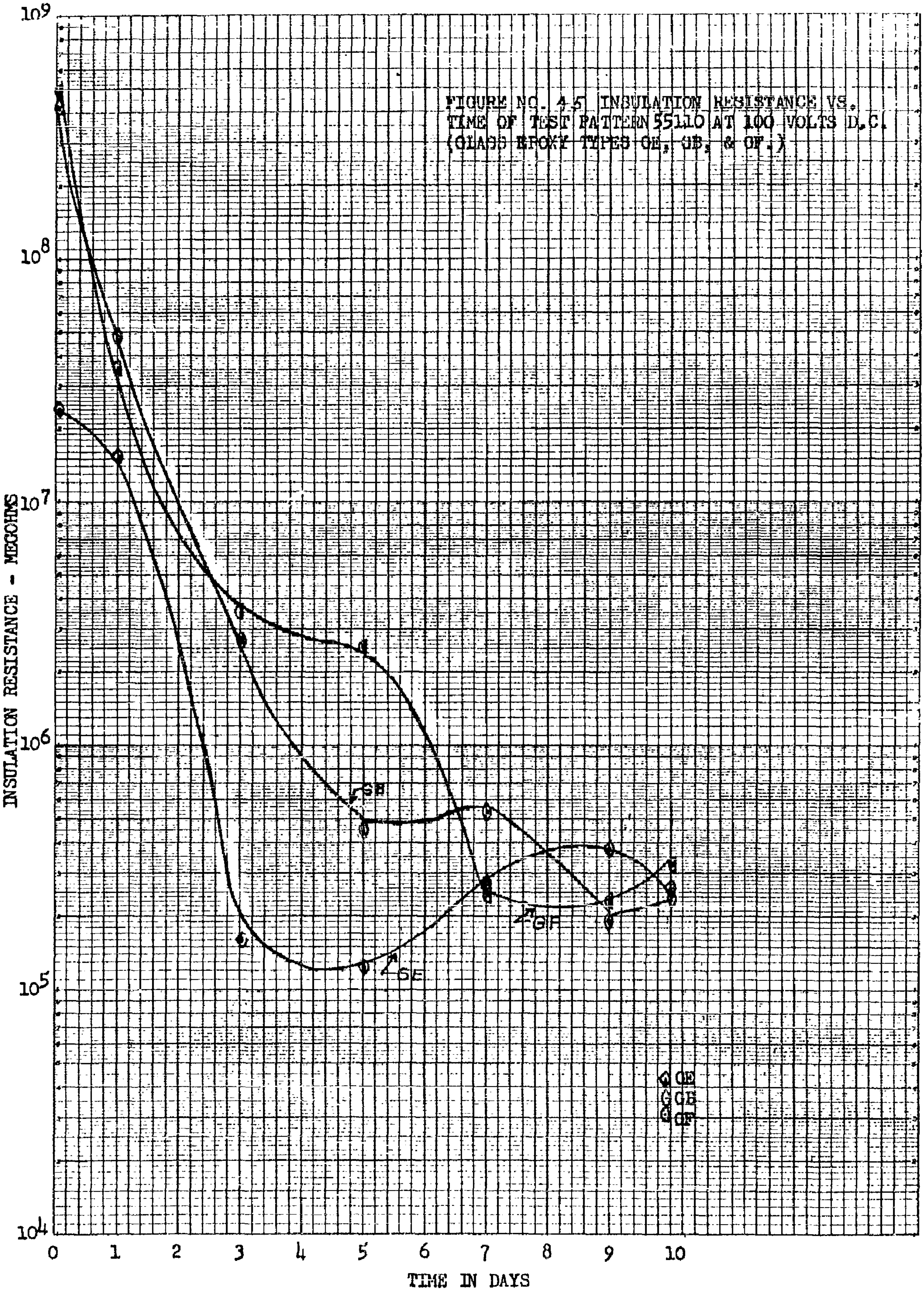


FIGURE NO. 45 INSULATION RESISTANCE VS. TIME OF TEST PATTERN 55110 AT 100 VOLTS D.C. (GLASS EPOXY TYPES GE, GB, & GF.)

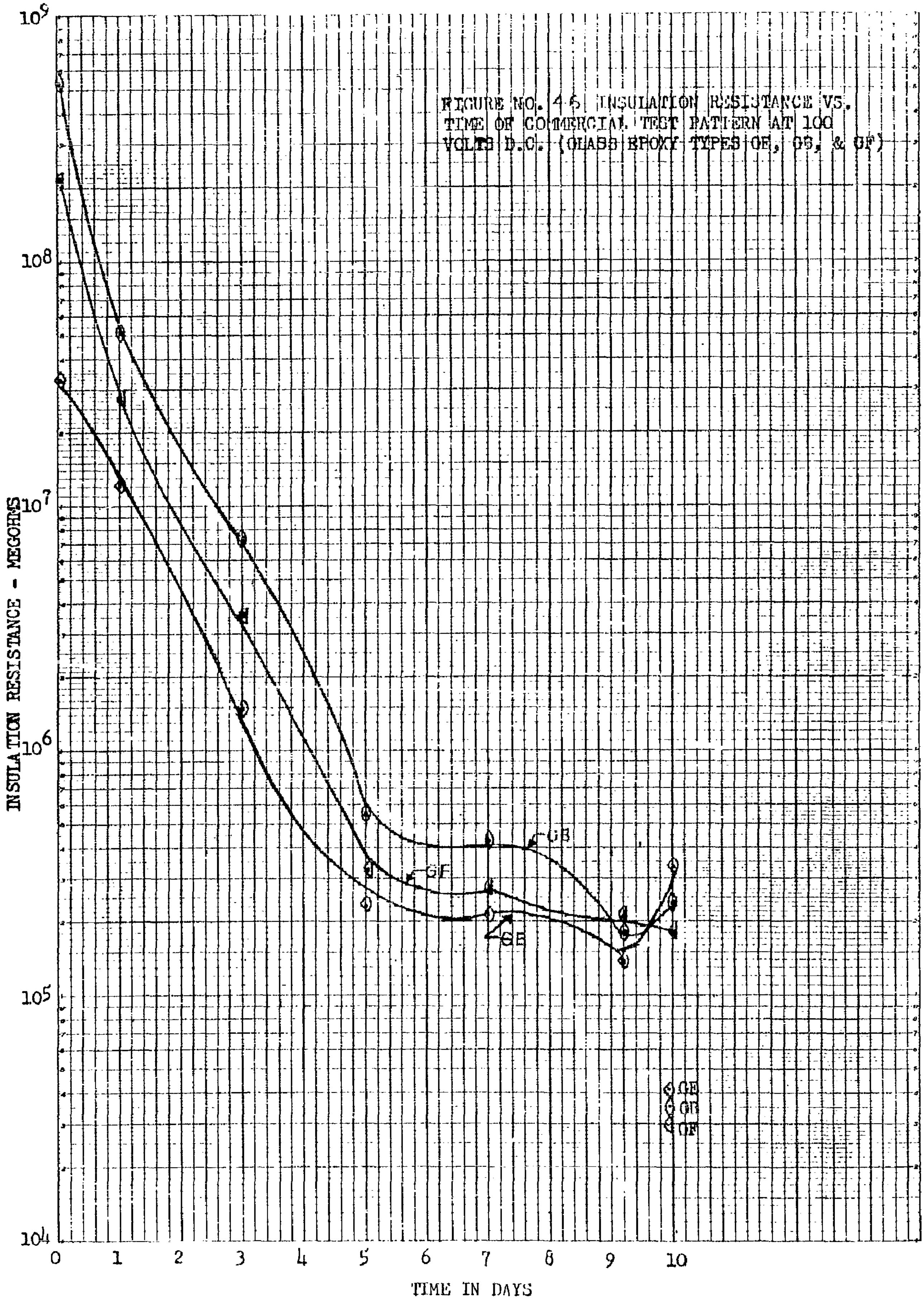


FIGURE NO. 46 INSULATION RESISTANCE VS. TIME OF COMMERCIAL TEST PATTERN AT 100 VOLTS D.C. (GLASS EPOXY TYPES GE, GB, & GF)

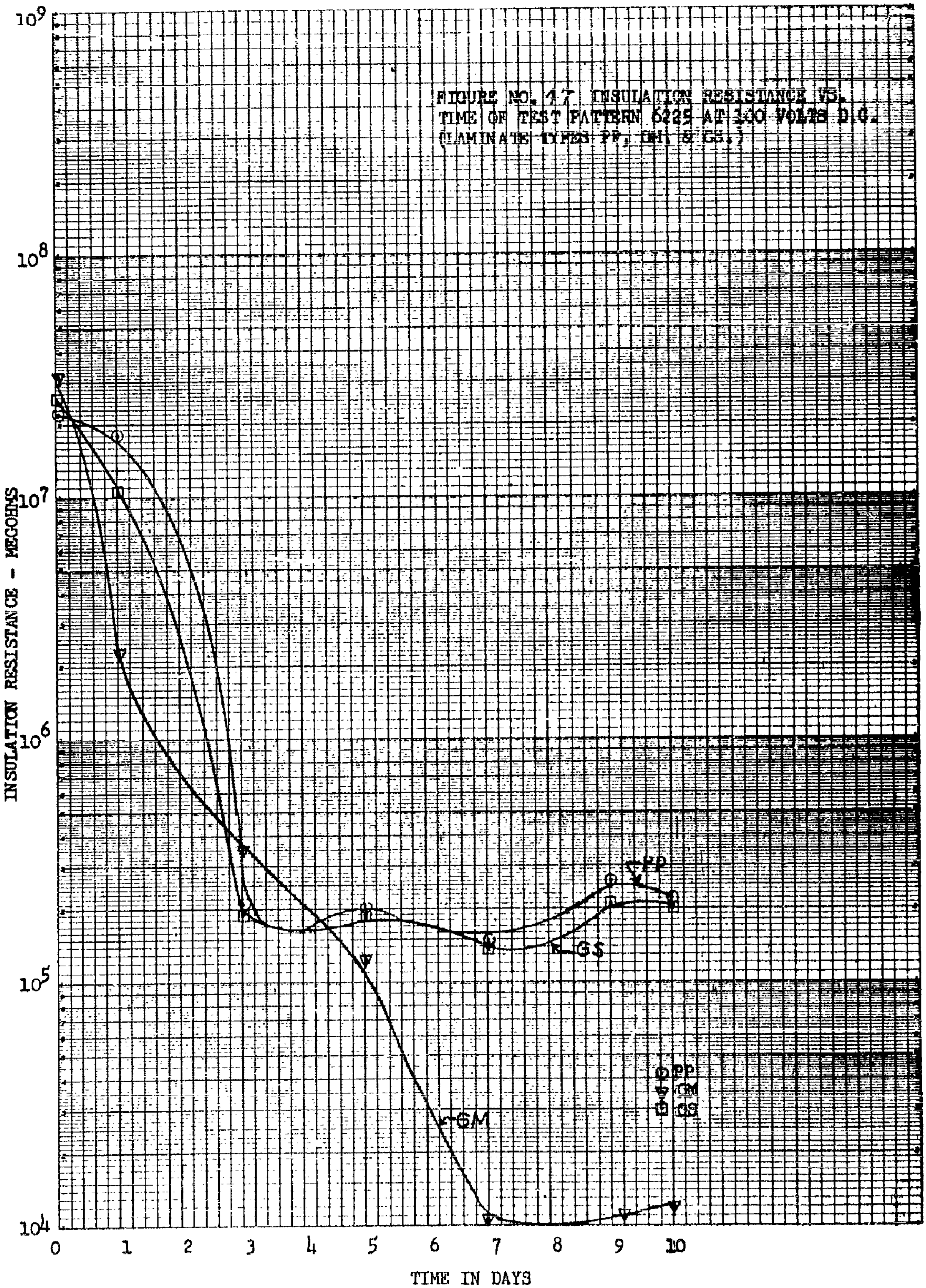


FIGURE NO. 47 INSULATION RESISTANCE VS. TIME OF TEST PATTERN 6225 AT 100 VOLTS D.C. (LAMINATE TYPES PP, GM, & GS.)
INSULATION RESISTANCE - MEGOHMS
10^9
10^8
10^7
10^6
10^5
10^4
0
1
2
3
4
5
6
7
8
9
10
TIME IN DAYS
PP
GS
GM
PP
GM
GS

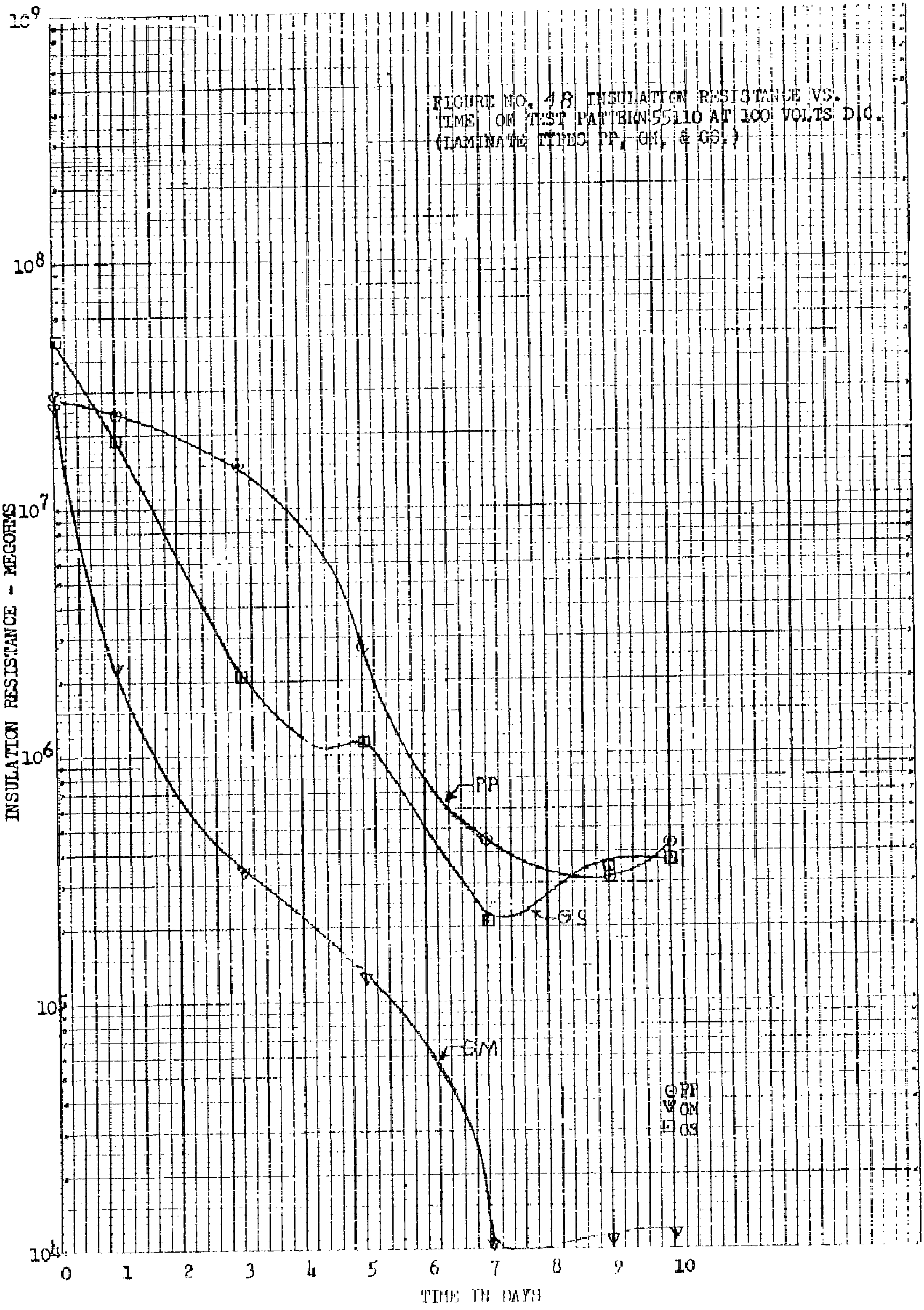


FIGURE NO. 48 INSULATION RESISTANCE VS. TIME ON TEST PATTERN 55110 AT 100 VOLTS D.C. (LAMINATE TYPES PP, GM, & GS.)
INSULATION RESISTANCE - MEGOHMS
TIME IN DAYS
PP
GS
GM
PP
GM
GS

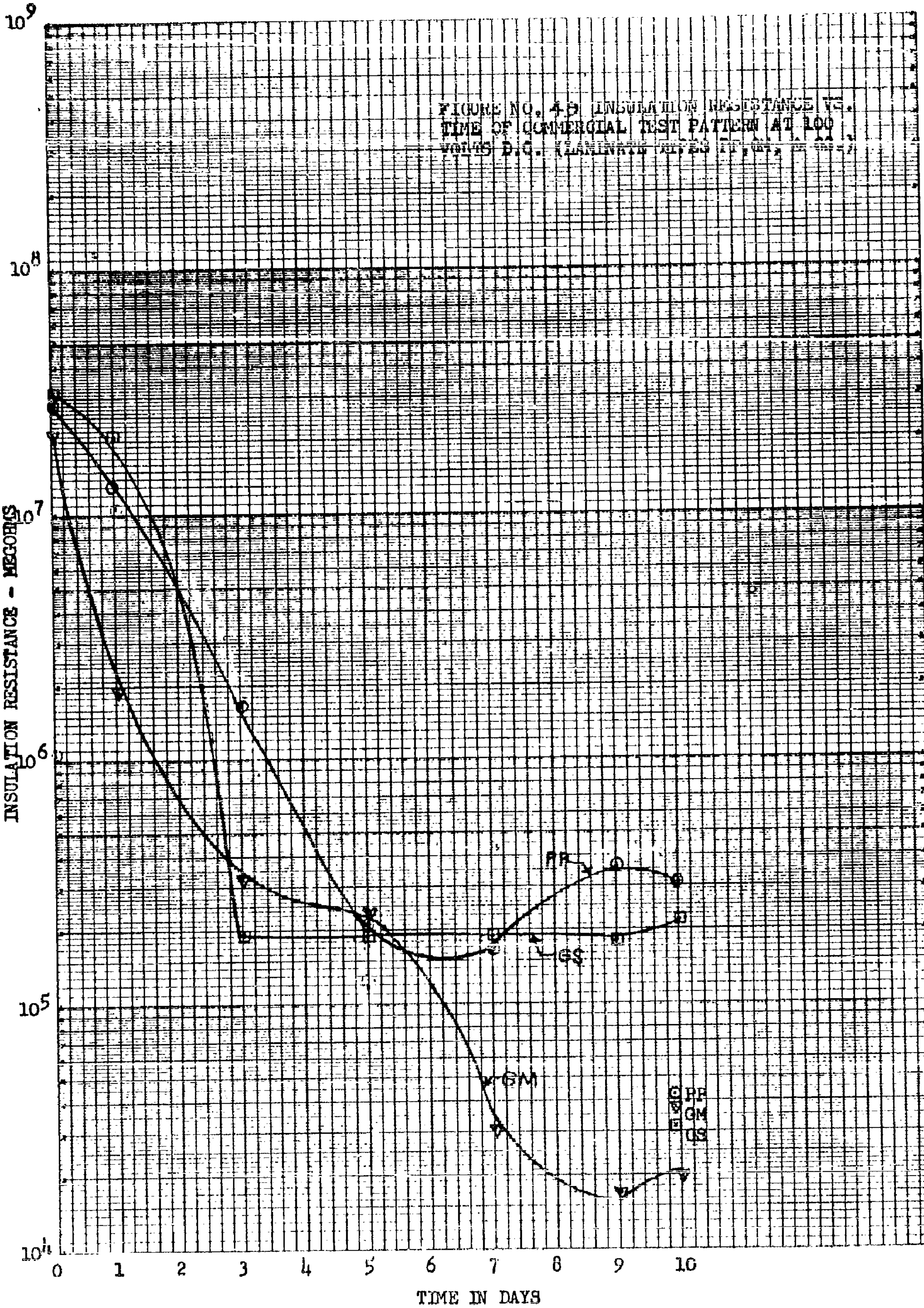


FIGURE NO. 4_ INSULATION RESISTANCE VS.
TIME OF COMMERCIAL TEST PATTERN AT 100
VOLTS D.C. (LAMINATE TYPES
10^9
10^8
10^7
10^6
10^5
10^4
INSULATION RESISTANCE - MEGOHMS
PP
GS
GM
PP
GM
GS
0
1
2
3
4
5
6
7
8
9
10
TIME IN DAYS

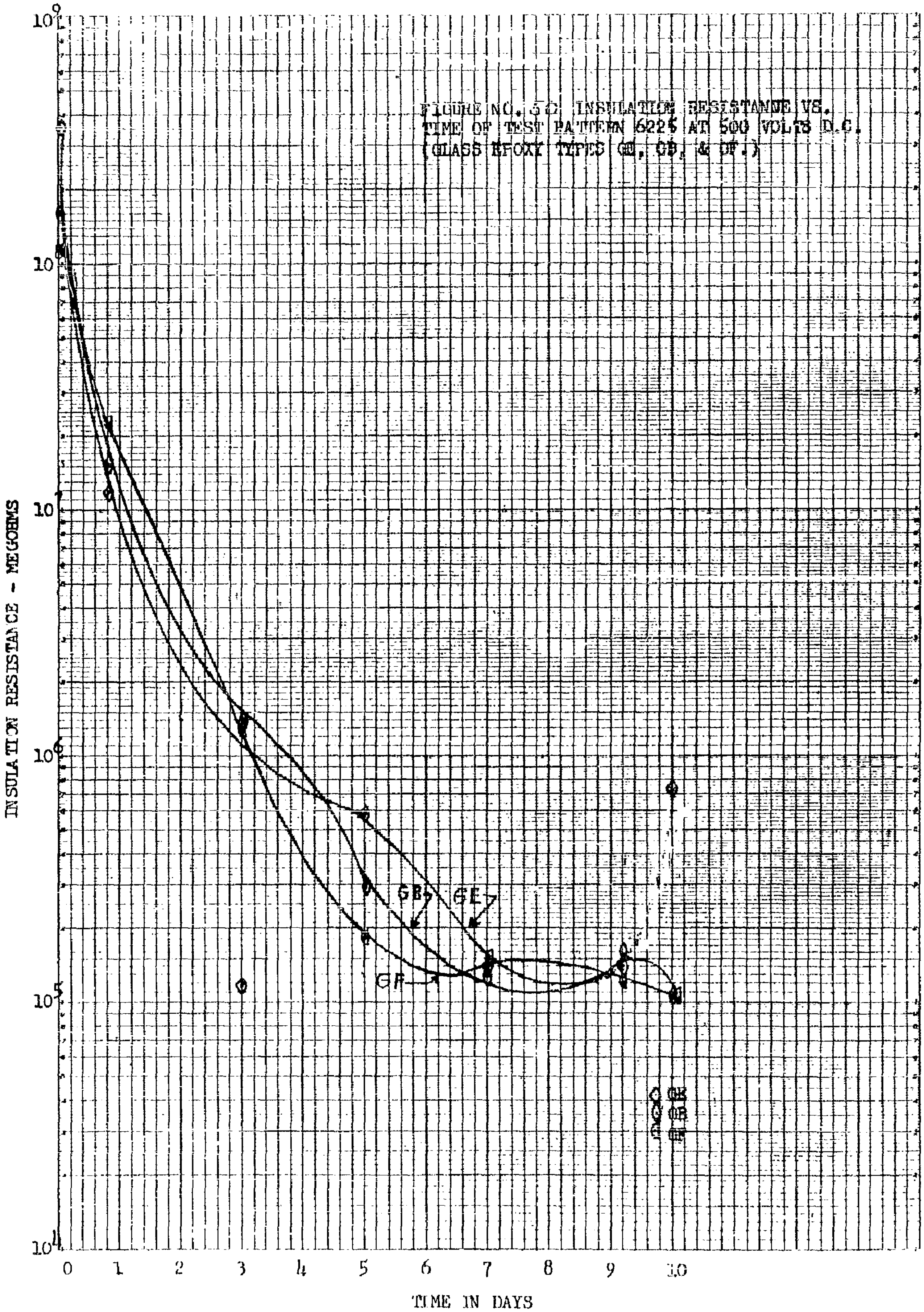


FIGURE NO. 5? INSULATION RESISTANCE VS. TIME OF TEST PATTERN 622$ AT 500 VOLTS D.C. (GLASS EPOXY TYPES GE, GB, & GF.)

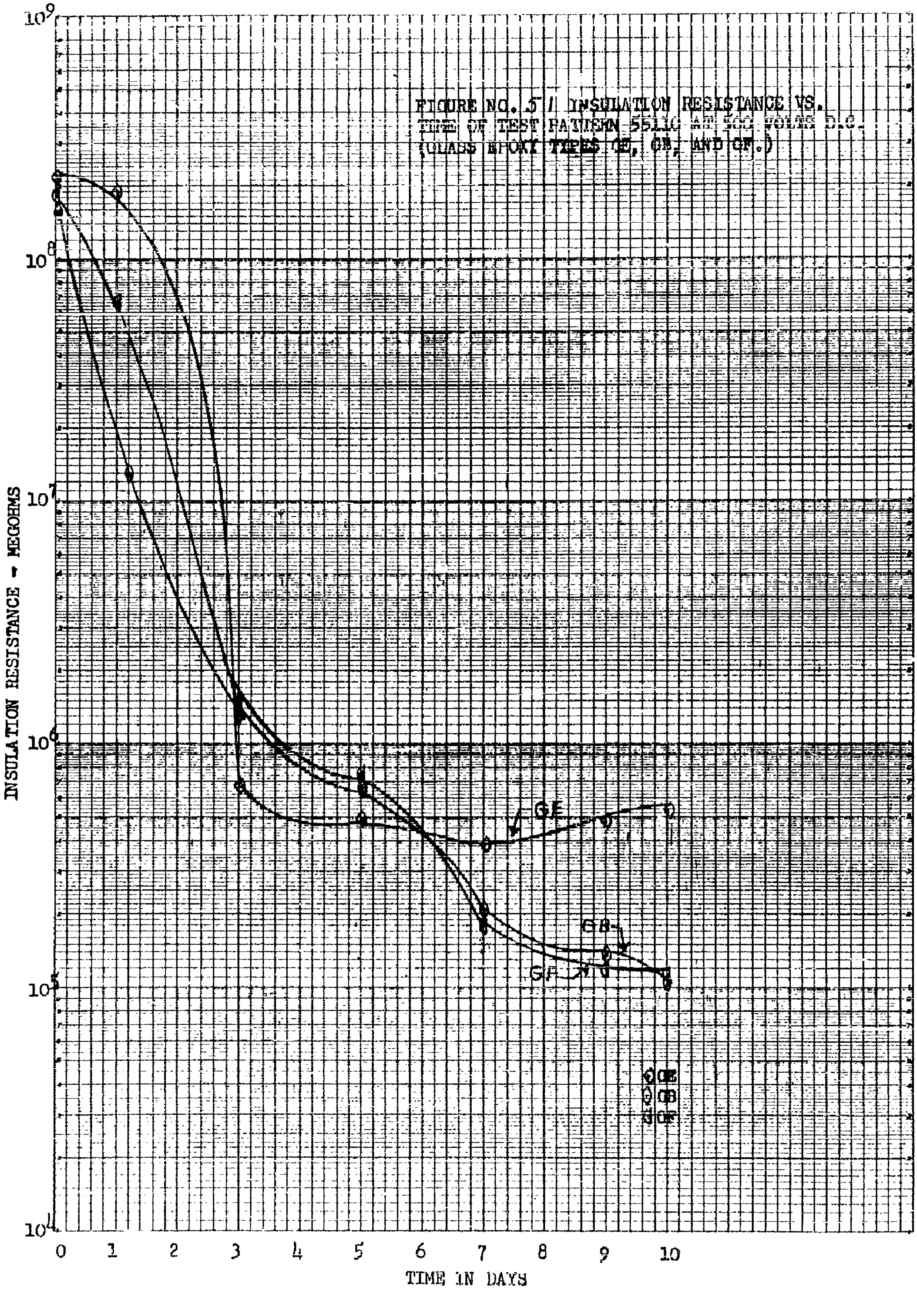


FIGURE NO. 51 INSULATION RESISTANCE VS. TIME OF TEST PATTERN 5511C AT [illegible] VOLTS D.C. (GLASS EPOXY TYPES GE, GB, AND GF.)

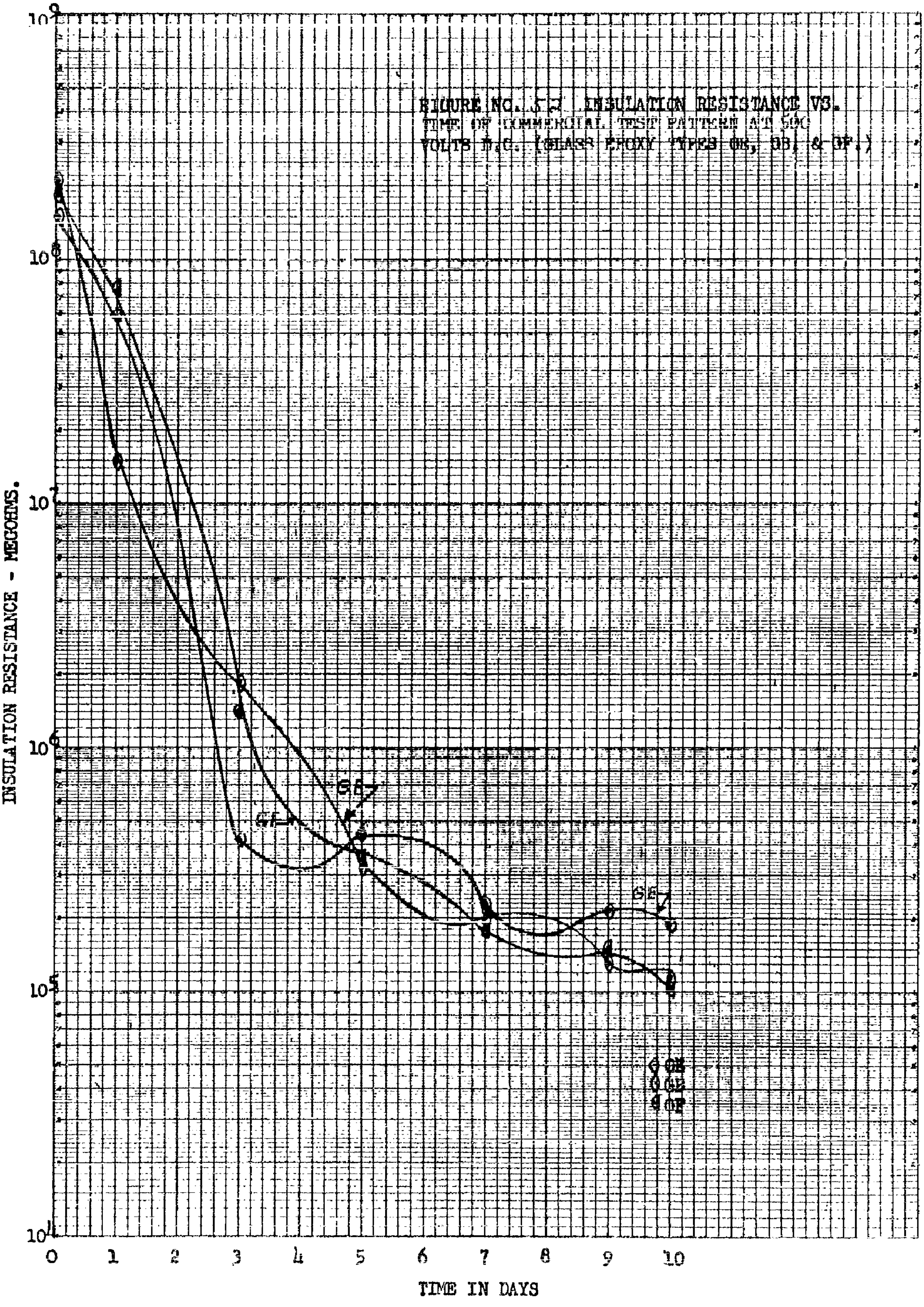


FIGURE NO. 5-7 INSULATION RESISTANCE VS. TIME OF COMMERCIAL TEST PATTERN AT 500 VOLTS D.C. (GLASS EPOXY TYPES GE, GB, & GF.)

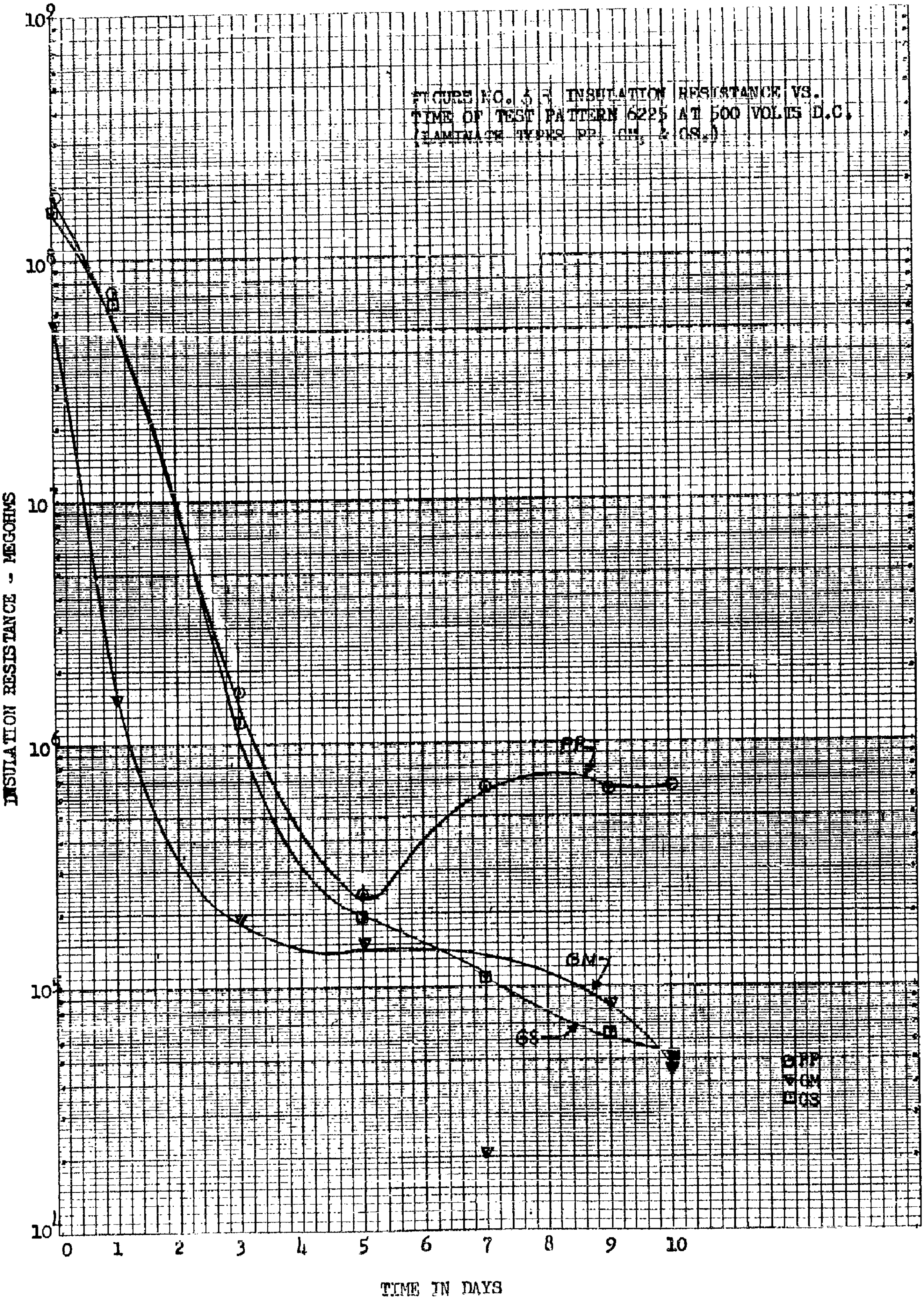


FIGURE NO. 55 INSULATION RESISTANCE VS.
TIME OF TEST PATTERN 6225 AT 500 VOLTS D.C.
(LAMINATE TYPES PP, GM, & GS.)
INSULATION RESISTANCE - MEGOHMS
10^9
10^8
10^7
10^6
10^5
10^4
0
1
2
3
4
5
6
7
8
9
10
TIME IN DAYS
PP
GM
GS
PP
GM
GS

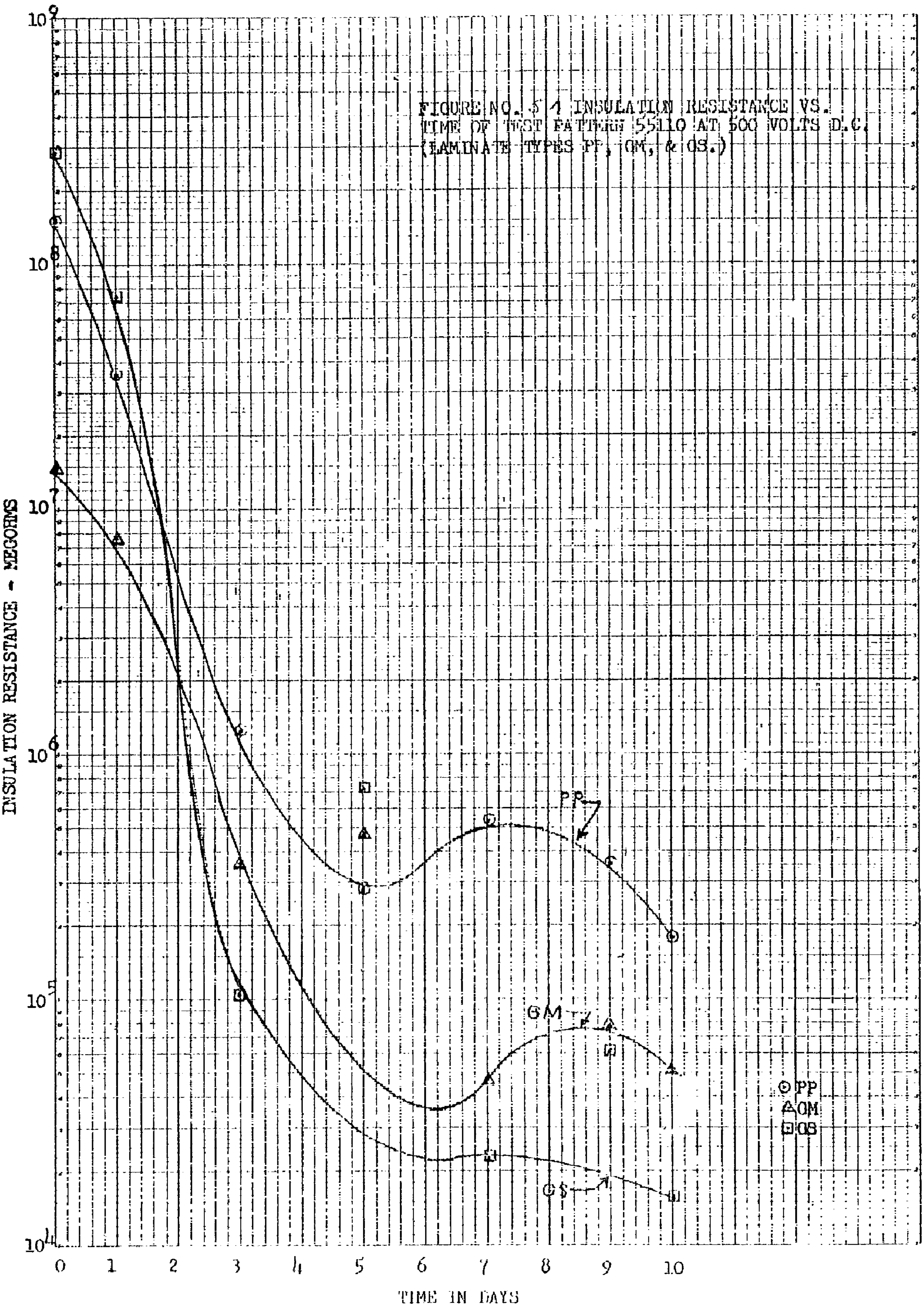


FIGURE NO. 5 4 INSULATION RESISTANCE VS. TIME OF TEST PATTERN 55110 AT 500 VOLTS D.C. (LAMINATE TYPES PP, OM, & OS.)
PP
OM
OS
INSULATION RESISTANCE - MEGOHMS
10^9
10^8
10^7
10^6
10^5
10^4
0
1
2
3
4
5
6
7
8
9
10
TIME IN DAYS

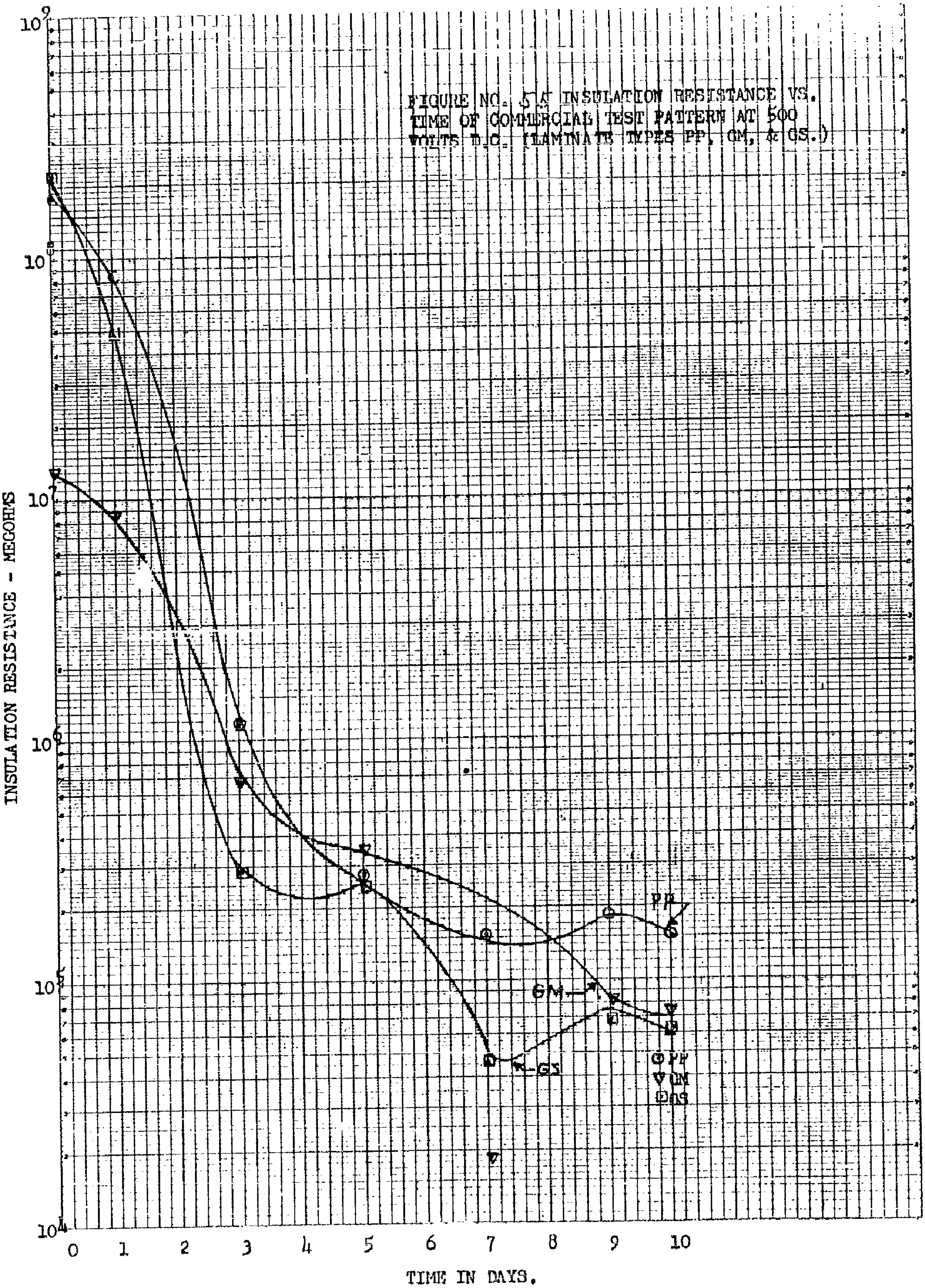
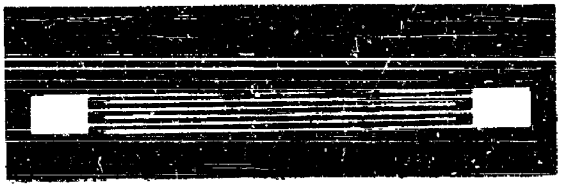
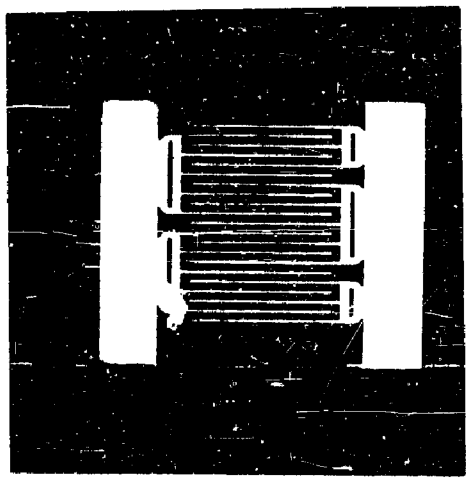


FIGURE NO. 5 A INSULATION RESISTANCE VS. TIME OF COMMERCIAL TEST PATTERN AT 500 VOLTS D.C. (LAMINATE TYPES PP, GM, & GS.)
INSULATION RESISTANCE - MEGOHMS
TIME IN DAYS.
PP
GM
GS
⊙ PP
▽ GM
⊡ GS



NO. - 6225 PATTERN

NO. - 55110 PATTERN



COMMERCIAL PATTERN

Figure No. 56. Insulation Resistance Test Patterns

obtained on the modified pattern to be used for this task. Comparative results are tabulated below:

INSULATION RESISTANCE (In Megohms)

Material	Test Volt	START OF TEST Modified Pattern	START OF TEST Regular Pattern	CONCLUSION OF TEST Modified Pattern	CONCLUSION OF TEST Regular Pattern
GE	500	2.36×10^8	2.44×10^8	3.2×10^5	4.61×10^5
GE	100	2.41×10^7	1.40×10^7	2.69×10^5	3.41×10^5
GB	500	1.52×10^8	1.75×10^8	1.14×10^5	1.25×10^5
GB	100	4.13×10^8	2.11×10^8	2.58×10^5	1.0×10^5
GF	500	1.80×10^8	1.40×10^8	1.12×10^5	1.18×10^5
GF	100	4.86×10^8	3.41×10^8	3.24×10^5	2.11×10^5
GM	500	1.3×10^7	1.3×10^7	5×10^4	7.11×10^4
GM	100	2.77×10^7	3.61×10^7	1.71×10^4	2.13×10^4
GS	500	2.94×10^8	2.75×10^8	1.64×10^4	1.55×10^4
GS	100	4.9×10^7	5.4×10^7	3.82×10^5	2.11×10^5
PX	500	7.60×10^7	2.41×10^7	2.12×10^5	2.01×10^5
PX	100	2.56×10^7	2.64×10^7	2.13×10^5	2.11×10^5
GT	500	3.33×10^8	3.14×10^8	1.33×10^5	1.41×10^5
GT	100	1.93×10^8	1.70×10^8	1.49×10^5	1.38×10^5

From the data presented in Tables XXIV through XXIX, and Figures 44 through 55, the correlation between all of the test patterns and base materials were fairly consistent in insulation resistance values when all 100 volt DC measurements are compared with each other and 500 volt DC measurements are compared with each other.

Tables XXX and XXXI show the insulation resistance test values of paper epoxy and glass teflon measured at 100 and 500 volts DC. Figures 57 through 60 show insulation resistance versus time of four different test pattern designs (6225, 55110, Com. and Bullseye) on paper epoxy and glass teflon base laminates. The initial resistance readings of the glass

TABLE XXX

INSULATION RESISTANCE TEST RESULTS OF PAPER EPOXY & GLASS TEFLON (100 VOLTS D.C.)

Board No.	Laminate Base & Pattern Design No.	INSULATION RESISTANCE (In Megohms) AT 100 VOLTS D.C. APPLIED TO EACH BOARD Initial Reading	First Day	Third Day	Fifth Day	Seventh Day	Ninth Day	Tenth Day
91	Paper Epoxy (PX) - 6225	3.45×10^{7}	2.64×10^{7}	3.00×10^{6}	*8.00×10^{5}	1.04×10^{5}	3.40×10^{5}	1.04×10^{5}
92	Paper Epoxy (PX) - 6225	3.65×10^{7}	4.55×10^{7}	4.60×10^{6}	3.00×10^{5}	1.10×10^{5}	7.48×10^{5}	1.98×10^{5}
93	Paper Epoxy (PX) - 6225	3.75×10^{7}	5.44×10^{7}	5.40×10^{6}	2.45×10^{5}	1.25×10^{5}	2.00×10^{5}	1.67×10^{5}
94	Paper Epoxy (PX) - 6225	3.25×10^{7}	3.75×10^{7}	3.40×10^{6}	2.00×10^{5}	1.08×10^{5}	1.50×10^{5}	1.78×10^{5}
95	Paper Epoxy (PX) - 6225	3.85×10^{7}	4.50×10^{7}	3.60×10^{6}	2.05×10^{5}	1.03×10^{5}	1.45×10^{5}	1.64×10^{5}
	Average Values	3.59×10^{7}	4.02×10^{7}	4.00×10^{6}	2.37×10^{5}	1.10×10^{5}	2.17×10^{5}	1.62×10^{5}
96	Paper Epoxy (PX) - 55110	2.04×10^{7}	4.50×10^{7}	1.64×10^{6}	3.45×10^{5}	*6.34×10^{5}	1.78×10^{5}	1.64×10^{5}
97	Paper Epoxy (PX) - 55110	2.35×10^{7}	3.60×10^{7}	2.40×10^{6}	4.60×10^{5}	2.00×10^{5}	1.34×10^{5}	1.79×10^{5}
98	Paper Epoxy (PX) - 55110	2.64×10^{7}	3.70×10^{7}	2.45×10^{6}	3.34×10^{5}	*7.00×10^{5}	1.78×10^{5}	1.94×10^{5}
99	Paper Epoxy (PX) - 55110	2.84×10^{7}	4.00×10^{7}	2.36×10^{6}	2.75×10^{5}	2.10×10^{5}	*3.00×10^{5}	2.44×10^{5}
100	Paper Epoxy (PX) - 55110	2.94×10^{7}	7.00×10^{7}	2.38×10^{6}	3.25×10^{5}	2.28×10^{5}	*4.34×10^{5}	2.84×10^{5}
	Average Values	2.56×10^{7}	3.95×10^{7}	2.25×10^{6}	3.48×10^{5}	2.12×10^{5}	1.63×10^{5}	2.13×10^{5}
101	Paper Epoxy (PX) -Com.	4.67×10^{7}	2.34×10^{7}	1.45×10^{6}	2.36×10^{5}	2.45×10^{5}	1.78×10^{5}	1.46×10^{5}
102	Paper Epoxy (PX) -Com.	4.34×10^{7}	3.40×10^{7}	1.64×10^{6}	2.12×10^{5}	1.98×10^{5}	1.05×10^{5}	1.64×10^{5}
103	Paper Epoxy (PX) -Com.	3.75×10^{7}	3.38×10^{7}	*3.04×10^{6}	2.87×10^{5}	2.64×10^{5}	1.17×10^{5}	1.34×10^{5}
104	Paper Epoxy (PX) -Com.	4.84×10^{7}	3.45×10^{7}	1.58×10^{6}	2.55×10^{5}	*3.45×10^{5}	2.04×10^{5}	*3.05×10^{5}
105	Paper Epoxy (PX) -Com.	4.64×10^{7}	2.95×10^{7}	1.25×10^{6}	2.45×10^{5}	*4.00×10^{5}	1.90×10^{5}	1.45×10^{5}
	Average Values	4.45×10^{7}	3.11×10^{7}	1.48×10^{6}	2.47×10^{5}	2.36×10^{5}	1.60×10^{5}	1.47×10^{5}

* - Not averaged in total.

TABLE XXX (CONT)

INSULATION RESISTANCE TEST RESULTS OF PAPER EPOXY & GLASS TEFLON (100 VOLTS D.C.)

Board No.	Laminate Base & Pattern Design No.	INSULATION RESISTANCE (In Megohms) AT 100 VOLTS D.C. APPLIED TO EACH BOARD						
		Initial Reading	First Day	Third Day	Fifth Day	Seventh Day	Ninth Day	Tenth Day
106	Glass Teflon (GT) 6225	1.96×10^{8}	1.37×10^{7}	4.00×10^{7}	1.45×10^{5}	3.40×10^{5}	1.85×10^{5}	1.23×10^{5}
107	Glass Teflon (GT) 6225	2.00×10^{8}	1.64×10^{7}	3.64×10^{7}	1.34×10^{5}	3.20×10^{5}	1.87×10^{5}	1.45×10^{5}
108	Glass Teflon (GT) 6225	2.40×10^{8}	1.87×10^{7}	3.75×10^{7}	1.54×10^{5}	2.04×10^{5}	1.75×10^{5}	1.65×10^{5}
109	Glass Teflon (GT) 6225	2.38×10^{8}	1.64×10^{7}	3.60×10^{7}	1.64×10^{5}	2.10×10^{5}	1.45×10^{5}	1.74×10^{5}
110	Glass Teflon (GT) 6225	2.95×10^{8}	1.34×10^{7}	3.70×10^{7}	1.74×10^{5}	2.08×10^{5}	1.28×10^{5}	1.27×10^{5}
	Average Values	2.34×10^{8}	1.57×10^{7}	3.74×10^{7}	1.54×10^{5}	2.07×10^{5}	1.64×10^{5}	1.47×10^{5}
111	Glass Teflon (GT) 55110	2.48×10^{8}	1.78×10^{7}	6.70×10^{6}	3.45×10^{5}	2.34×10^{5}	1.64×10^{5}	1.68×10^{5}
112	Glass Teflon (GT) 55110	1.65×10^{8}	2.75×10^{7}	5.00×10^{6}	3.10×10^{5}	2.24×10^{5}	2.07×10^{5}	1.24×10^{5}
113	Glass Teflon (GT) 55110	1.25×10^{8}	*4.67×10^{7}	7.00×10^{6}	3.24×10^{5}	2.65×10^{5}	2.17×10^{5}	1.56×10^{5}
114	Glass Teflon (GT) 55110	2.40×10^{8}	1.89×10^{7}	5.00×10^{6}	3.54×10^{5}	2.78×10^{5}	2.40×10^{5}	1.48×10^{5}
115	Glass Teflon (GT) 55110	1.87×10^{8}	1.95×10^{7}	6.04×10^{6}	3.75×10^{5}	2.25×10^{5}	2.80×10^{5}	1.49×10^{5}
	Average Values	1.93×10^{8}	2.09×10^{7}	5.95×10^{6}	3.42×10^{5}	2.46×10^{5}	2.22×10^{5}	1.49×10^{5}
116	Glass Teflon (GT)-Com.	3.04×10^{8}	4.60×10^{7}	1.64×10^{6}	2.65×10^{5}	1.46×10^{5}	1.65×10^{5}	1.45×10^{5}
117	Glass Teflon (GT)-Com.	3.25×10^{8}	4.78×10^{7}	2.40×10^{6}	2.44×10^{5}	2.40×10^{5}	1.24×10^{5}	1.78×10^{5}
118	Glass Teflon (GT)-Com.	3.68×10^{8}	4.25×10^{7}	2.25×10^{6}	2.55×10^{5}	2.60×10^{5}	1.34×10^{5}	1.60×10^{5}
119	Glass Teflon (GT)-Com.	3.40×10^{8}	4.70×10^{7}	2.10×10^{6}	2.61×10^{5}	2.90×10^{5}	1.54×10^{5}	1.40×10^{5}
120	Glass Teflon (GT)-Com.	3.80×10^{8}	4.84×10^{7}	1.75×10^{6}	2.34×10^{5}	2.40×10^{5}	1.49×10^{5}	1.68×10^{5}
	Average Values	3.43×10^{8}	4.63×10^{7}	2.03×10^{6}	2.52×10^{5}	2.35×10^{5}	1.12×10^{5}	1.58×10^{5}

* - Not averaged in total.

TABLE XXX (CONT)

INSULATION RESISTANCE TEST RESULTS OF PAPER EPOXY & GLASS TEFLON (100 VOLTS D.C.)

Board No.	Laminate Base & Pattern Design No.	INSULATION RESISTANCE (In Megohms) AT 100 VOLTS D.C. APPLIED TO EACH BOARD						
		Initial Reading	First Day	Third Day	Fifth Day	Seventh Day	Ninth Day	Tenth Day
121	Paper Epoxy (PX) Bullseye	2.64×10^{7}	5.05×10^{7}	4.50×10^{6}	1.67×10^{6}	1.95×10^{5}	1.04×10^{5}	1.56×10^{5}
122	Paper Epoxy (PX) Bullseye	*9.00×10^{7}	6.78×10^{7}	3.85×10^{6}	1.27×10^{6}	2.45×10^{5}	*6.76×10^{5}	1.19×10^{5}
123	Paper Epoxy (PX) Bullseye	3.64×10^{7}	5.45×10^{7}	3.75×10^{6}	1.47×10^{6}	2.04×10^{5}	1.47×10^{5}	1.14×10^{5}
124	Paper Epoxy (PX) Bullseye	*6.45×10^{7}	5.85×10^{7}	3.64×10^{6}	1.32×10^{6}	2.17×10^{5}	1.28×10^{5}	1.35×10^{5}
125	Paper Epoxy (PX) Bullseye	3.41×10^{7}	4.87×10^{7}	3.94×10^{6}	1.79×10^{6}	2.04×10^{5}	1.67×10^{5}	2.50×10^{5}
	Average Values	3.23×10^{7}	5.60×10^{7}	3.94×10^{6}	1.50×10^{6}	2.13×10^{5}	1.37×10^{5}	1.55×10^{5}
126	Glass Teflon (GT) Bullseye	2.06×10^{8}	1.28×10^{7}	1.79×10^{6}	4.64×10^{6}	*6.76×10^{5}	2.78×10^{5}	1.92×10^{5}
127	Glass Teflon (GT) Bullseye	*4.67×10^{8}	1.19×10^{7}	1.46×10^{6}	2.94×10^{6}	4.50×10^{5}	2.65×10^{5}	2.00×10^{5}
128	Glass Teflon (GT) Bullseye	2.50×10^{8}	1.11×10^{7}	2.07×10^{6}	3.45×10^{6}	4.25×10^{5}	1.95×10^{5}	1.25×10^{5}
129	Glass Teflon (GT)	1.92×10^{8}	1.25×10^{7}	2.25×10^{6}	*7.00×10^{6}	4.95×10^{5}	*4.00×10^{5}	1.28×10^{5}
130	Glass Teflon (GT) Bullseye	1.67×10^{8}	1.28×10^{7}	1.95×10^{6}	3.85×10^{6}	4.84×10^{5}	1.14×10^{5}	1.67×10^{5}
	Average Values	2.04×10^{8}	1.22×10^{7}	1.91×10^{6}	3.97×10^{6}	4.54×10^{5}	2.13×10^{5}	1.62×10^{5}

* - Not averaged in total.

TABLE XXXI

INSULATION RESISTANCE TEST RESULTS OF PAPER EPOXY & GLASS TEFLON (500 VOLTS D.C.)

Board No.	Laminate Base & Pattern Design No.	INSULATION RESISTANCE (in Megohms) AT 500 VOLTS D.C. APPLIED TO EACH BOARD: Initial Reading	First Day	Third Day	Fifth Day	Seventh Day	Ninth Day	Tenth Day
91	Paper Epoxy (PX) 6225	1.64×10^{7}	2.34×10^{7}	5.68×10^{6}	2.34×10^{5}	1.67×10^{5}	1.3[illegible] $\times 10^{5}$	1.40×10^{5}
92	Paper Epoxy (PX) 6225	1.34×10^{7}	*6.70×10^{7}	7.45×10^{6}	1.46×10^{5}	1.95×10^{5}	*8.60×10^{5}	1.95×10^{5}
93	Paper Epoxy (PX) 6225	3.64×10^{7}	1.45×10^{7}	3.45×10^{6}	1.28×10^{5}	1.75×10^{5}	1.34×10^{5}	1.28×10^{5}
94	Paper Epoxy (PX) 6225	2.35×10^{7}	1.85×10^{7}	4.85×10^{6}	1.75×10^{5}	1.84×10^{5}	2.34×10^{5}	1.44×10^{5}
95	Paper Epoxy (PX) 6225	1.88×10^{7}	2.65×10^{7}	6.34×10^{6}	1.95×10^{5}	1.28×10^{5}	2.01×10^{5}	1.60×10^{5}
	Average Values	2.17×10^{7}	2.07×10^{7}	5.55×10^{6}	1.76×10^{5}	1.70×10^{5}	1.76×10^{5}	1.51×10^{5}
96	Paper Epoxy (PX) 55110	2.34×10^{7}	2.00×10^{7}	3.45×10^{6}	6.45×10^{5}	4.00×10^{5}	3.37×10^{5}	*6.70×10^{5}
97	Paper Epoxy (PX) 55110	1.94×10^{7}	1.04×10^{7}	3.20×10^{6}	6.38×10^{5}	4.67×10^{5}	3.84×10^{5}	1.20×10^{5}
98	Paper Epoxy (PX) 55110	[illegible]	1.00×10^{7}	3.85×10^{6}	6.75×10^{5}	4.94×10^{5}	3.25×10^{5}	2.50×10^{5}
99	Paper Epoxy (PX) 55110	2.64×10^{7}	1.89×10^{7}	*1.20×10^{6}	5.65×10^{5}	4.05×10^{5}	2.95×10^{5}	2.85×10^{5}
100	Paper Epoxy (PX) 55110	2.90×10^{7}	1.80×10^{7}	3.98×10^{6}	5.67×10^{5}	4.25×10^{5}	1.95×10^{5}	1.95×10^{5}
	Average Values	2.60×10^{7}	1.55×10^{7}	3.62×10^{6}	6.22×10^{5}	4.38×10^{5}	3.07×10^{5}	2.12×10^{5}
101	Paper Epoxy (PX)-Com.	5.65×10^{7}	1.06×10^{7}	3.00×10^{6}	3.45×10^{5}	2.95×10^{5}	[illegible]	1.25×10^{5}
102	Paper Epoxy (PX)-Com.	7.00×10^{7}	1.60×10^{7}	2.00×10^{6}	3.25×10^{5}	2.08×10^{5}	1.95×10^{5}	1.84×10^{5}
103	Paper Epoxy (PX)-Com.	6.08×10^{7}	1.70×10^{7}	1.28×10^{6}	3.85×10^{5}	2.65×10^{5}	1.94×10^{5}	2.06×10^{5}
104	Paper Epoxy (PX)-Com.	5.85×10^{7}	1.95×10^{7}	2.50×10^{6}	3.90×10^{5}	2.47×10^{5}	1.80×10^{5}	1.64×10^{5}
105	Paper Epoxy (PX)-Com.	5.75×10^{7}	1.25×10^{7}	2.65×10^{6}	3.05×10^{5}	2.27×10^{5}	1.25×10^{5}	1.54×10^{5}
	Average Values	6.06×10^{7}	1.52×10^{7}	2.28×10^{6}	3.50×10^{5}	2.48×10^{5}	1.79×10^{5}	1.67×10^{5}

* - Not averaged in total.

TABLE XXXI (CONT)

INSULATION RESISTANCE TEST RESULTS OF PAPER EPOXY & GLASS TEFLON (500 VOLTS D.C.)

Board No.	Laminate Base & Pattern Design No.	INSULATION RESISTANCE (In Megohms) AT 500 VOLTS D.C. APPLIED TO EACH BOARD Initial Reading	First Day	Third Day	Fifth Day	Seventh Day	Ninth Day	Tenth Day
106	Glass Teflon (GT) - 6225	3.45×10^8	2.95×10^7	1.46×10^6	3.00×10^5	3.45×10^5	4.05×10^5	*9.04×10^5
107	Glass Teflon (GT) - 6225	3.04×10^8	3.40×10^7	1.08×10^6	2.00×10^5	3.67×10^5	4.06×10^5	6.00×10^5
108	Glass Teflon (GT) - 6225	2.94×10^8	*6.00×10^7	1.25×10^6	4.25×10^5	3.34×10^5	4.09×10^5	3.95×10^5
109	Glass Teflon (GT) - 6225	6.40×10^8	3.40×10^7	1.34×10^6	5.40×10^5	3.74×10^5	4.24×10^5	4.00×10^5
110	Glass Teflon (GT) - 6225	8.80×10^8	2.95×10^7	1.80×10^6	3.45×10^5	3.34×10^5	5.34×10^5	3.44×10^5
	Average Values	4.92×10^8	2.54×10^7	1.38×10^6	3.62×10^5	3.50×10^5	4.36×10^5	4.35×10^5
111	Glass Teflon (GT) - 55110	3.45×10^8	1.05×10^7	2.08×10^6	4.00×10^5	3.45×10^5	2.45×10^5	1.09×10^5
112	Glass Teflon (GT) - 55110	3.01×10^8	1.25×10^7	2.80×10^6	4.00×10^5	3.24×10^5	2.40×10^5	1.25×10^5
113	Glass Teflon (GT) - 55110	2.85×10^8	1.68×10^7	2.25×10^6	3.84×10^5	2.84×10^5	2.17×10^5	1.64×10^5
114	Glass Teflon (GT) - 55110	*5.00×10^8	1.75×10^7	2.90×10^6	4.65×10^5	3.34×10^5	2.25×10^5	1.67×10^5
115	Glass Teflon (GT) - 55110	4.00×10^8	1.28×10^7	3.04×10^6	4.24×10^5	3.45×10^5	2.40×10^5	1.95×10^5
	Average Values	3.33×10^8	1.40×10^7	2.61×10^6	4.14×10^5	3.46×10^5	2.33×10^5	1.33×10^5
116	Glass Teflon (GT) - Com.	7.00×10^8	6.94×10^7	5.45×10^6	3.64×10^5	2.45×10^5	1.98×10^5	1.95×10^5
117	Glass Teflon (GT) - Com.	7.64×10^8	6.78×10^7	5.87×10^6	4.56×10^5	2.10×10^5	2.25×10^5	2.06×10^5
118	Glass Teflon (GT) - Com.	8.45×10^8	6.78×10^7	5.37×10^6	4.78×10^5	2.34×10^5	2.84×10^5	2.47×10^5
119	Glass Teflon (GT) - Com.	5.34×10^8	6.25×10^7	5.98×10^6	4.25×10^5	2.24×10^5	2.60×10^5	2.84×10^5
120	Glass Teflon (GT) - Com.	6.37×10^8	6.34×10^7	4.50×10^6	*6.00×10^5	2.10×10^5	2.40×10^5	2.98×10^5
	Average Values	6.96×10^8	6.62×10^7	5.43×10^6	4.31×10^5	2.24×10^5	2.41×10^5	2.46×10^5

* - Not averaged in total.

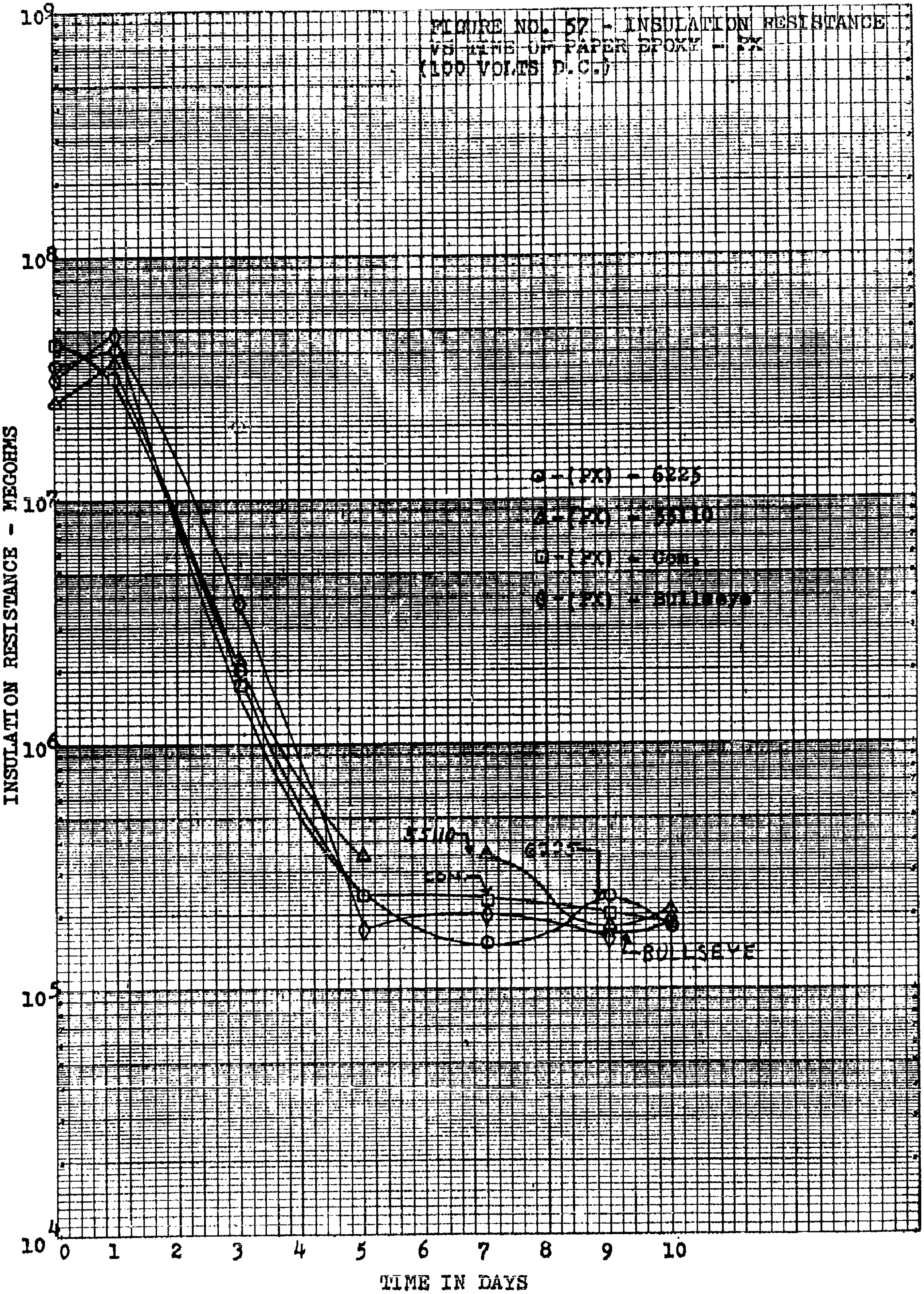


FIGURE NO. 57 - INSULATION RESISTANCE VS TIME OF PAPER EPOXY - PX (100 VOLTS D.C.)

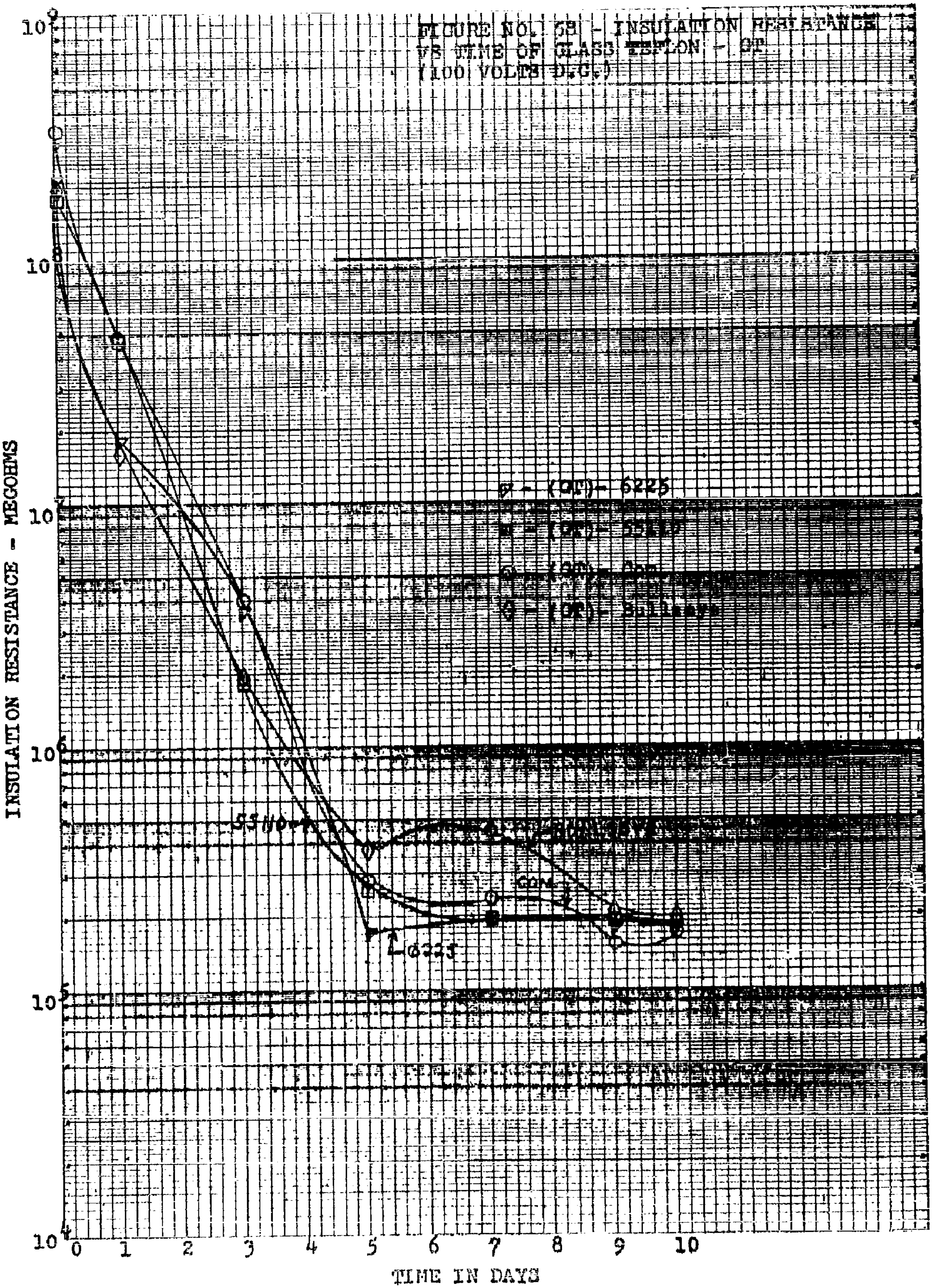


FIGURE NO.
INSULATION RESISTANCE
VS TIME OF GLASS TEFLON - QT
(100 VOLTS D.C.)
(QT)- 6225
55 Nov
6225
Con
INSULATION RESISTANCE - MEGOHMS
10^9
10^8
10^7
10^6
10^5
10^4
0
1
2
3
4
5
6
7
8
9
10
TIME IN DAYS

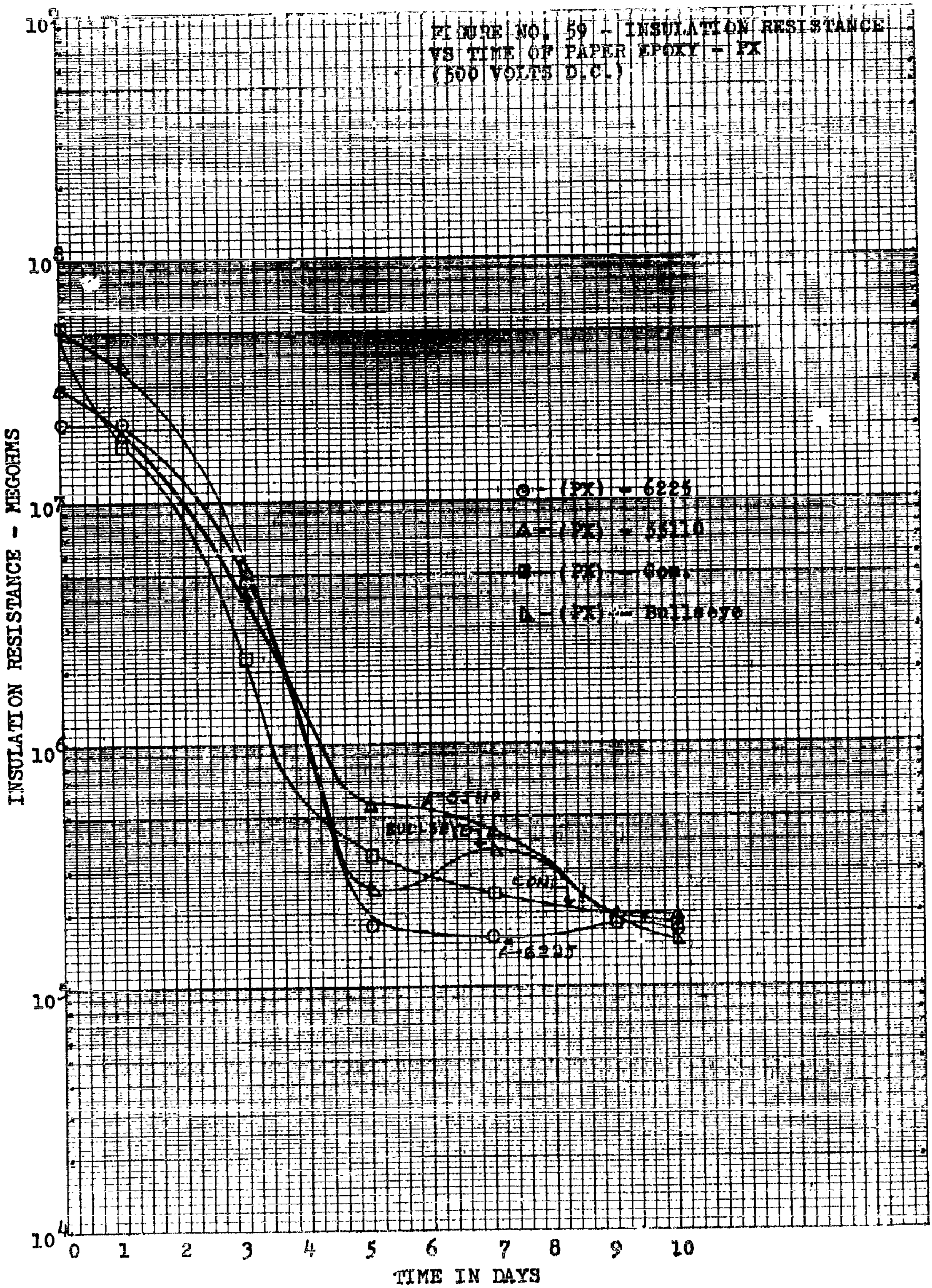
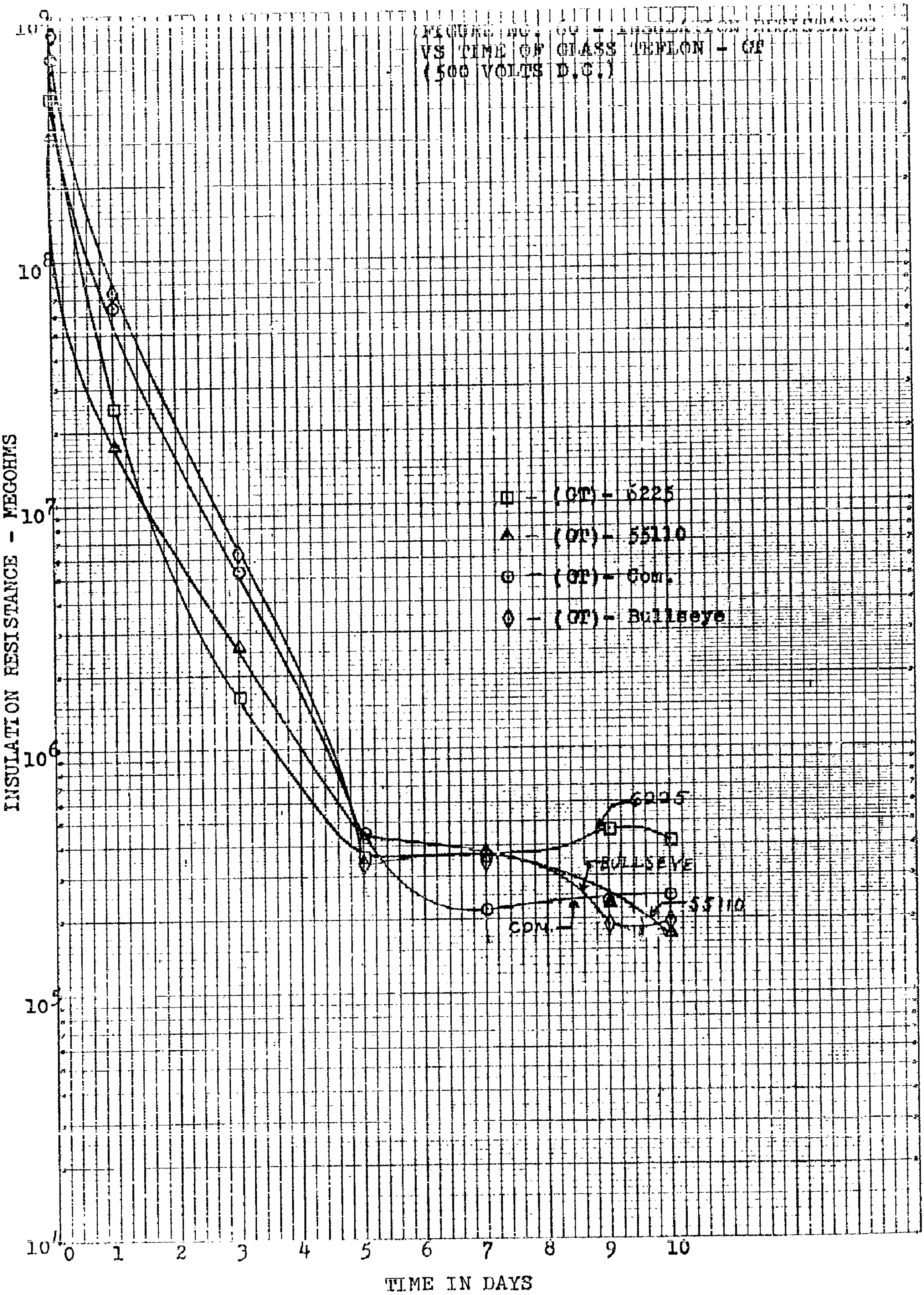


FIGURE NO. 59 - INSULATION RESISTANCE VS TIME OF PAPER EPOXY - PX (500 VOLTS D.C.)


VS TIME OF GLASS TEFLON - GT
(500 VOLTS D.C.)
(GT) - 6225
(GT) - 55110
(GT) - Com.
(GT) - Bullseye
6225
BULLSEYE
55110
COM.
INSULATION RESISTANCE - MEGOHMS
10^9
10^8
10^7
10^6
10^5
10^4
0
1
2
3
4
5
6
7
8
9
10
TIME IN DAYS

teflon specimens were higher than the paper epoxy specimens. Other than this one variation between these curves in Figures 57 through 60, good reproducible resistance values both at 100 and 500 volts DC was accomplished for paper epoxy and glass teflon base laminates.

Test boards 111 through 126 were bullseye test specimens on several types of base laminates, tested to establish the technique for measuring insulation resistance under humidity conditions, the effect of different cleaning procedures and to compare insulation resistance values for reproducibility of results between bullseye patterns and the comb patterns. See Table XXXII for the surface resistance values reported in megohms, and Figures 61 and 62 for the change in surface resistance values during 10 day humidity cycling condition.

There was very little effect on the insulation resistance measurements when employing the two types of cleaning procedures as described in paragraph 3.2 of this Task. The paper epoxy and glass teflon insulation test specimens were cleaned by the second cleaning method as described in paragraph 3.2.1 of this Task. This method is more practical in production and will still produce clean surfaces of any test specimens which would be tested for insulation resistance.

Bases on this work under Task B, an insulation resistance test procedure to give reproducible insulation resistance test results is described in Appendix C at the end of this report.

3.6 Conclusions

1. The measurement of insulation resistance under humidity chamber conditions can be effectively accomplished on either a comb pattern or a bullseye pattern. A number of reasons however, dictate the strong recommendation that the bullseye be used in preference to the comb, these are:

   a) The bullseye may be used not only for insulation resistance, but also for volume and surface resistivity. This is not practical with a comb.

   b) When the comb pattern line spacing is less than .060 inches, and measurements are made with 500 volt potential, more erratic results are obtained.

   c) When wires must be soldered to the pattern for external connection to measuring equipment, there is more possibility of flux or solder contamination between conductors.

   d) The bullseye pattern is more easily standardized.

2. The following factors, based on the work performed in this Task, should be followed in order to properly design a humidity cabinet which will give consistent and reproducible insulation resistance readings (under any humidifying conditions).

   a) All conductors inside the chamber should be teflon insulated shielded coaxial cable.

   b) Any insulation material needed for internal chamber fixtures should be made of teflon because of its high electrical resistance and water repellant qualities.

   c) All terminal electrode connections should be designed so that they may be grounded either during testing or when idle. (Grounding is necessary to prevent stray electrostatic charges from building up on the test specimen surface.)

   d) A current leakage history of each functional part of the test chamber should be performed to determine the degree of current leakage that is taking place when using

TABLE XXXII

CALCULATED SURFACE RESISTANCE VALUES ON BULLSEYE SPECIMENS

Board No.	Humidity Chamber Position	Copper Foil Weight	Type & Thickness of Laminate (Inch)	Initial Reading	Surface Resistance (Rs) In Megohms					
					First Day	Second Day	Eighth Day	Ninth Day	Tenth Day	Final Reading
1	II-E3	1 oz/1S	1/16-GE	8.06×10^{6}	3.12×10^{6}	1.04×10^{6}	1.51×10^{6}	1.47×10^{6}	2.18×10^{3}	4.35×10^{6}
2	II-E5	1 oz/1S	1/16-GE	6.58×10^{6}	1.19×10^{6}	0.54×10^{6}	0.80×10^{6}	0.51×10^{6}	1.47×10^{3}	3.52×10^{6}
3	II-E7	1 oz/1S	1/16-GE	5.82×10^{6}	1.32×10^{6}	1.56×10^{6}	0.64×10^{6}	2.86×10^{6}	0.58×10^{3}	3.38×10^{6}
4	II-E9	1 oz/1S	1/16-GE	8.06×10^{6}	1.79×10^{6}	0.91×10^{6}	0.86×10^{6}	0.63×10^{6}	2.71×10^{3}	3.26×10^{6}
5	II-F3	1 oz/1S	1/16-GE	7.82×10^{6}	1.92×10^{6}	1.32×10^{6}	3.58×10^{6}	1.92×10^{6}	0.71×10^{3}	4.15×10^{6}
6	II-G7	1 oz/1S	1/16-GE	8.06×10^{6}	1.47×10^{6}	0.83×10^{6}	2.38×10^{6}	0.70×10^{6}	1.72×10^{3}	3.52×10^{3}
	Average Values			7.38×10^{6}	1.80×10^{6}	1.03×10^{6}	1.63×10^{6}	1.35×10^{6}	1.56×10^{3}	3.69×10^{6}
7	II-F5	1 oz/2S	1/16-GB	4.0×10^{5}	10.9×10^{4}	7.8×10^{4}	0.67×10^{5}	1.47×10^{5}	1.35×10^{5}	4.55×10^{5}
8	II-F7	1 oz/2S	1/16-GB	4.03×10^{5}	9.6×10^{4}	8.3×10^{4}	1.19×10^{5}	1.19×10^{5}	1.04×10^{5}	4.76×10^{5}
9	II-F9	1 oz/2S	1/16-GB	3.94×10^{5}	8.1×10^{4}	263 *	1.92×10^{5}	1.78×10^{5}	735 *	5.57×10^{6} *
10	II-G3	1 oz/2S	1/16-GB	0.56×10^{5} *	8.3×10^{4}	6.5×10^{4}	5.00×10^{4} *	3.33×10^{5}	2.70×10^{5}	5.57×10^{5} *
11	II-G5	1 oz/2S	1/16-GB	4.38×10^{5}	9.6×10^{4}	8.2×10^{4}	0.62×10^{5}	5.0×10^{5}	1.39×10^{5}	0.72×10^{5} *
12	II-G9	1 oz/2S	1/16-GB	3.45×10^{5}	8.9×10^{4}	8.9×10^{4}	2.78×10^{5}	1.67×10^{5}	2.08×10^{5}	5.0×10^{5}
	Average Values			4.06×10^{5}	9.2×10^{4}	8.0×10^{4}	1.44×10^{5}	1.89×10^{5}	1.72×10^{5}	4.78×10^{5}
13	II-H3	1 oz/2S	1/16-XXXP	9.62×10^{7}	2.94×10^{6}	1.85×10^{6}	$.96 \times 10^{6}$	2.08×10^{6}	5.56×10^{5}	2.70×10^{5}
14	II-H5	1 oz/2S	1/16-XXXP	7.05×10^{7}	2.60×10^{6}	4.16×10^{6}	1.09×10^{6}	2.17×10^{6}	10.0×10^{5}	2.56×10^{5}
	Average Values			8.33×10^{7}	2.77×10^{6}	3.030×10^{6}	1.030×10^{6}	2.12×10^{6}	7.80×10^{5}	2.63×10^{5}

* - Not averaged in total.

TABLE XXXII (CONT)

CALCULATED SURFACE RESISTANCE VALUES ON BULLSEYE SPECIMENS

Board No.	Humidity Chamber Position	Copper Foil Weight	Type & Thickness of Laminate (Inch)	Initial Reading	Surface Resistance (Rs) in Megohms					
					First Day	Second Day	Eighth Day	Ninth Day	Tenth Day	Final Reading
15	II-H7	1 oz/2S	1/16-XXXP	7.82×10^6	6.56×10^5	1.47×10^4	4.35×10^4	3.40×10^4	1.85×10^4	10.80×10^6
16	II-H9	1 oz/2S	1/16-XXXP	8.20×10^6	0.79×10^4*	0.52×10^4	5.00×10^3	3.57×10^3	1.85×10^3*	9.81×10^6
Average Values				8.0×10^6	6.56×10^5	1.0×10^4	--	--	--	10.30×10^6

* - Not averaged in total.

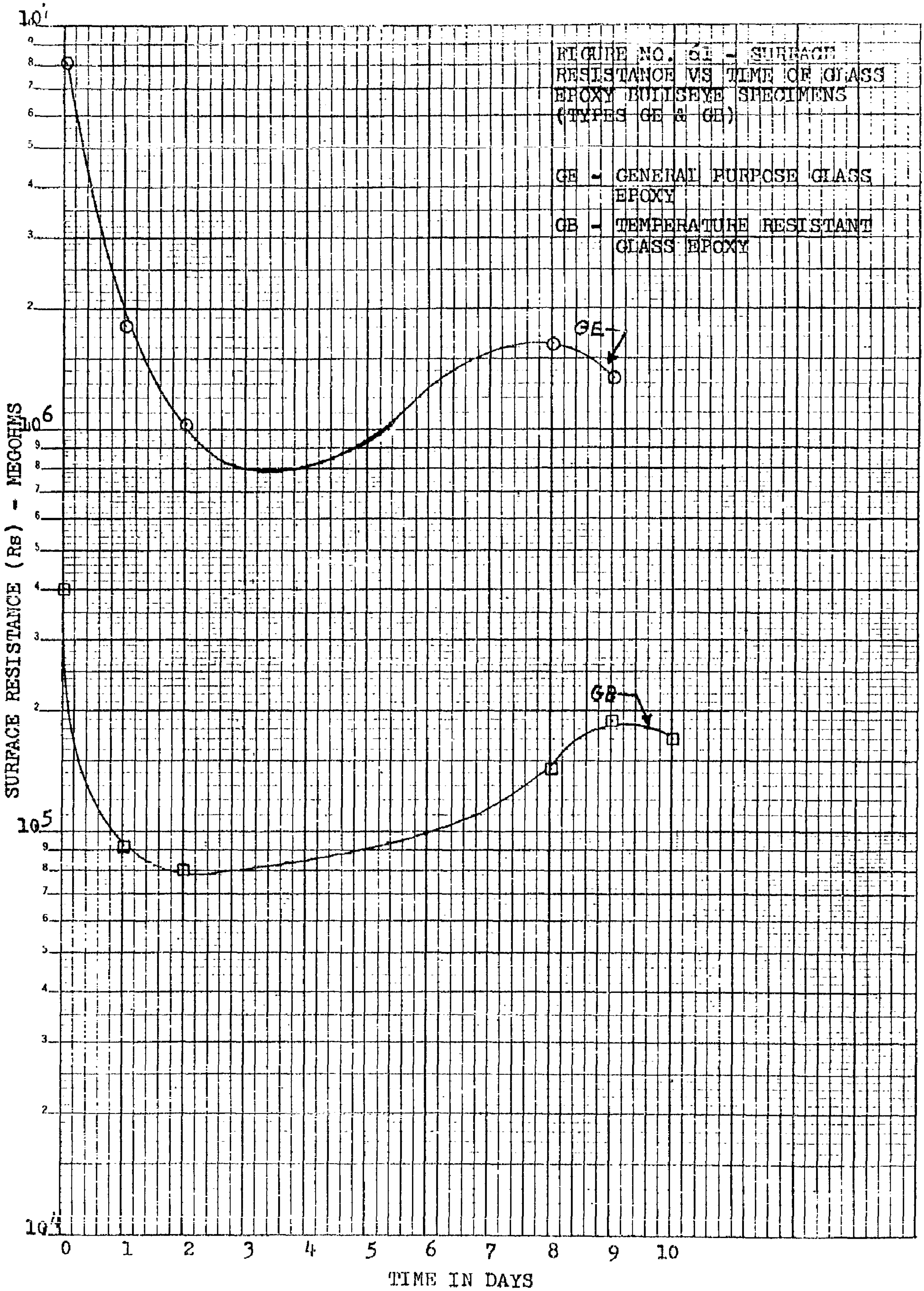


FIGURE NO. 61 - SURFACE RESISTANCE VS TIME OF GLASS EPOXY BULLSEYE SPECIMENS (TYPES GE & GB)
GE - GENERAL PURPOSE GLASS EPOXY
GB - TEMPERATURE RESISTANT GLASS EPOXY
GE
GB
SURFACE RESISTANCE (Rs) - MEGOHMS
TIME IN DAYS
0
1
2
3
4
5
6
7
8
9
10

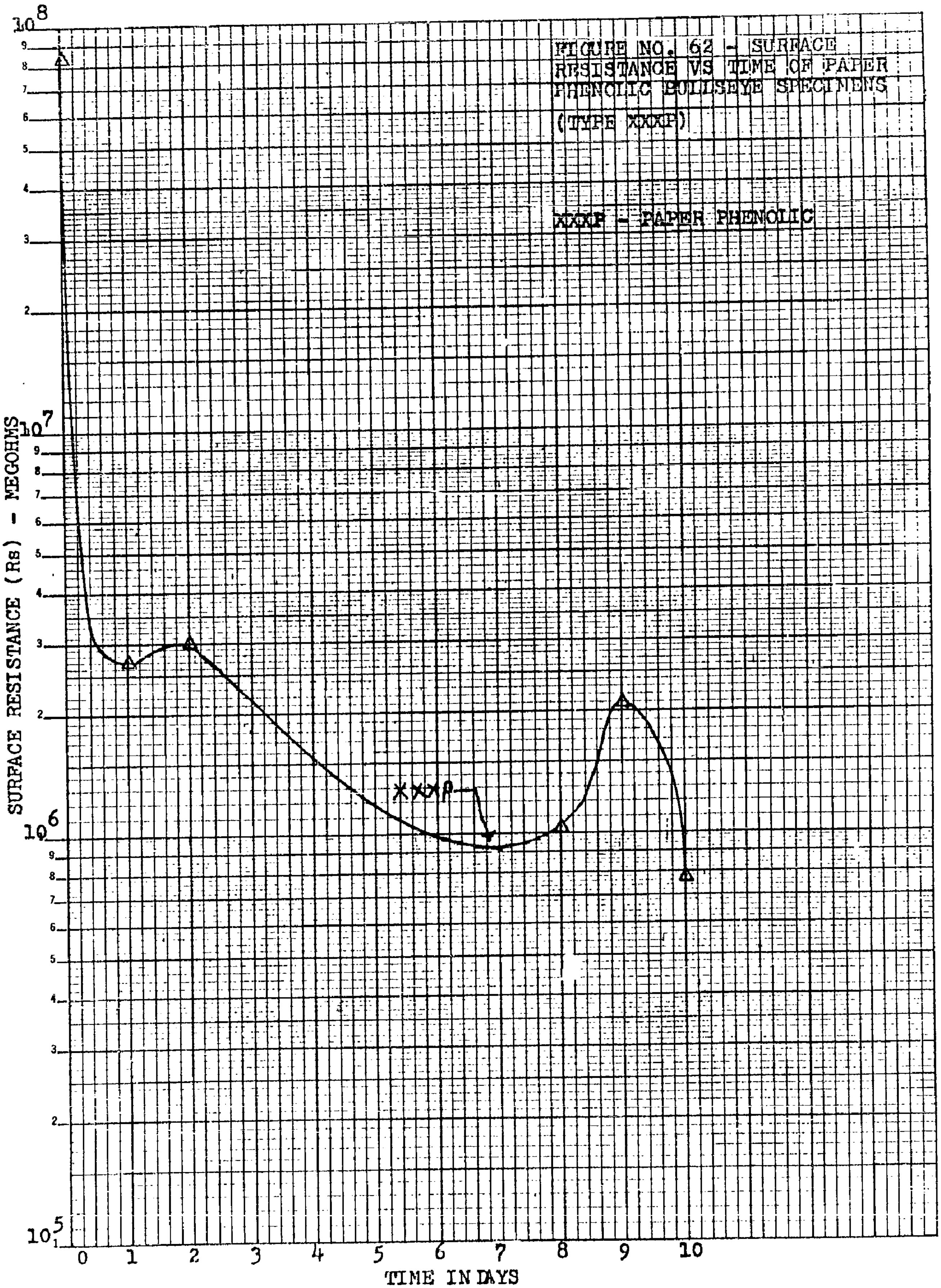


FIGURE NO. 62 - SURFACE RESISTANCE VS TIME OF PAPER PHENOLIC BULLSEYE SPECIMENS
(TYPE XXXP)
XXXP - PAPER PHENOLIC
XXXP
SURFACE RESISTANCE (Rs) - MEGOHMS
TIME IN DAYS
10^8
10^7
10^6
10^5
0 1 2 3 4 5 6 7 8 9 10

a 500 volt DC power source. Measurements should be made without samples connected to the electrodes and under the same humidity conditions used in testing.

c) Current leakage should be at least one power of 10 less than the current required for the sample being tested. (This means the conditioning cabinet and coaxal leads should have a current leakage rate less than material being tested in order to give good representative insulation test values for material being tested.)

3. The instrumentation for measuring insulation resistance (surface and volume resistance) to an accuracy of ±6% at 10^{14} ohms range can be accomplished by the indirect method. The resistance values are figured by measuring the current with a Keithley Electrometer Model 610A and dividing the current reading into the DC voltage applied to the test specimen. (It should be kept in mind that the voltage supply must be accurately known.)

4. It was found that either cleaning procedure, as stated in paragraph 3.2.1 cleaned the copper surface well enough to reduce contamination and enable good test results.

5. Specimens to be measured should be pre-conditioned at 80^{0} $\pm 3^{0}$C for one hour in an air circulating oven and handled with lint free gloves. This pre-conditioning is necessary to insure uniform readings of specimens at start of test.

6. Insulation test patterns 6225, 55110 (as described in Military Specifications SCL-6225 and MIL-P-55110 respectively), and the commercial comb pattern on base material glass epoxy types GE, GB and GF paper phenolic and glass silicone, had final insulation resistance values (at the end of 10 day cycling) within 25% of each other when measured at 100 volts DC.

7. The insulation resistance of glass melamine when measured at 100 volts DC was about 100 times lower than the laminates mentioned in conclusion 6.

8. Insulation resistance measurements made at 500 volts DC were not as consistent as at 100 volts DC. This was probably due to an incorrect air gap between conductors. (The air gap was only .030 in. which is 50% lower than what is generally required for 500 volt DC measurements when insulation resistance values are required.)

9. The insulation resistance values of test patterns 6225, 55110 and commercial comb patterns on paper epoxy and glass teflon (measured at 100 and 500 volts DC) were within 15% of each other.

10. The glass epoxy GB bullseye specimens copper clad on one side give a higher surface resistance reading than copper clad on two sides.

4. Task C - Peel Strength After Dip Solder

4.1 Approach

To perform peel strength tests on specimens tested after solder dip in accordance with test method specified in MIL-P-13949B. To evaluate reproducibility of test results by comparing results using specified method with results obtained by introducing such variables as (a) controlled amounts of solder deposited on specimens and (b) removal of excess solder by some suitable means.

To accomplish the above approach, two procedures are discussed; (1) vertical solder dip, and (2) chemical etching of a solder deposited film on copper.

4.2 Specimen Fabrication

The peel strength test patterns were made as specified in MIL-P-13949B. The base materials used for the peel strength specimens were as follows:

1. Phenolic resin - paper base (type PP)
2. Epoxy resin - paper base (type PX)
3. Epoxy resin - glass fabric base (type GE, GB & GF)
4. Silicone resin - glass fabric (type GS)
5. Melamine resin - glass fabric (type GM)
6. Teflon resin - glass fabric (type GT)

Five specimens, 1" x 3" x 1/8" thick were made for each of the material types as specified above and additional five specimens 1" x 3" x 1/32" thick made of paper base phenolic and paper base epoxy base materials. In all cases, one complete series of specimens were made with one oz. copper one side and one complete series with two oz. copper one side. Five specimens were prepared for each type of material from at least three manufacturers. The printing, etching and cleaning of the specimens were done as outlined in Appendix b at the back of the report.

4.3 Test Procedures for Controlling Solder Deposit

The solder bath temperatures are as specified in MIL-P-13949B. To establish a method which could be related to production procedures a dip solder approach was used to relate effect of the solder deposit on peel strength values. The following procedures are discussed below:

4.3.1 Vertical Solder Dip - Several test specimens of each base laminate (1 and 2 oz. copper) out of a group of five specimens were first cleaned as outlined in Appendix B. The surface of the copper peel strip on the base laminate was coated with a flux before dip soldered. Specimen was then vertically dipped into the solder bath. The immersion time for each specimen was dependant on the type of base material as specified in MIL-P-13949B. While the specimen was being removed from the solder bath, a silicone rubber scraper was used to remove the excess solder from the copper surface. Tests indicated tnat a solder film range of 0.1 to 0.8 MIL was obtained (film tolerance of + 0.2 MIL) on the surface of the copper when the above procedure was followed.

4.3.2 Chemical Etching of Solder Deposited Film on Copper - The balance of three specimens of each group of five specimens per vendor for each base material were solder dipped by immersing the specimen horizontally with the copper surface face down to the solder bath in accordance with the procedure in MIL-P-13949B. Dipping the specimen in this fashion allowed approximately a 14-18 MIL solder film to be deposited on the copper surface of the test specimen. Initially, several specimens were etched with varying concentrations of hydrochloric acid (HCL) and sodium hydroxide solutions (NAOH). The concentration of both solutions was varied from 25 to 75% but was found to be impractical to use as an etchant to etch away the solder film from the base copper because of chemical attack to the base laminate and copper adhesive in some cases. After further investigation a commercial lead-tin stripper solution No. 1101 was found which was non-corrosive to the base copper, and showed no evidence of chemical attack on any of the test specimens. The rate of etching away a solder film from the base copper was found to be 1 MIL per 10 minutes of soaking.

Although the rate of etching away the solder film from the copper strip was uniform, the original test specimens had an irregular solder film thickness on each specimen, with variations of solder film thickness from one end of the specimen to the other ranging from 1 and 4 MILS. Therefore, only a uniform rate of etching away the solder film was achieved. Knowing the rate of etching the solder film away from the copper strip, an estimated time for arriving at a per-determined solder film thickness was achieved only to the extent that the original unetched solder film copper strip test specimen was fairly uniform in solder film thickness. The base copper thickness was measured first and then the total thickness of both copper and solder film was measured. Several readings were taken per specimen to arrive at an average solder film thickness at the point the peel strip was peeled.

4.4 Analysis of Peel Test Results

The dip soldering and chemical etching operations were performed on 225 test specimens as described in paragraph 4.3. The peel strength test results of these test specimens are reported in Tables 33 through 50. In the column marked Chemical Etching Solution, (see tables 33 through 50) those specimens marked with a number 1101 have been chemically etched before peel testing. The other specimens were either tested in "as dipped" condition or wiped.

Figure No. 63 shows two specimens of glass epoxy (GE) and two of glass melamine (GM) before and after peel testing, respectively. The peel strength test results reported in Tables 33 through 50 were plotted in Figures 64 through 71 to show the variation of peel strength (lbs./inch-width) with varying amounts of solder on the copper surface.

The graphical results show that with increasing solder film thickness on a copper test strip the peel strength increases. It should be noted that the peel strength increases at a faster rate with 1-5 MILS of solder film on the copper than any further increase of solder film thickness (Figures 64 - 69). Because of a large variation of peel strength test results on the base laminates tested, no reproducibility basis could be arrived at between the types of base materials tested, (refer to paragraph 4.2 for laminate types). Because there was an appreciable variation between the peel test results on the base laminates tested, only a band showing an approximate upper and lower limit could be shown, (Figures 64 through 71).

The glass teflon peel test data showed very low peel strength as compared to the rest of the peel test results, (see Figures 70 and 71). This is undoubtedly due to the normal difficulties involved in bonding to a fluorcarbon surface because of the nonwetability characteristics of this material.

TABLE XXXIII

PEEL STRENGTH TEST RESULTS AFTER SOLDER DIP AND CHEMICAL ETCHING OF PAPER PHENOLIC (1/32 INCH THICKNESS - 1 OZ.COPPER)

Spec. No.	Base Laminate	Laminate Thickness (Inch)	Copper Weight (Oz.)	Copper Foil Thickness Inch (10^{-3})	Solder Film Thickness Inch (10^{-3})	Manufacturer	Peel Strength After Dip Solder (Lbs/In. Width)	Chemical Etching Solution No.
1	Paper Phenolic (PP)	1/32	1	1.4	0.10	A	9.00	----
2	Paper Phenolic (PP)	1/32	1	1.4	4.60	A	16.00	----
3	Paper Phenolic (PP)	1/32	1	1.4	17.60	A	16.40	----
4	Paper Phenolic (PP)	1/32	1	1.4	7.60	A	15.60	1101
5	Paper Phenolic (PP)	1/32	1	1.4	13.60	A	18.00	1101
6	Paper Phenolic (PP)	1/32	1	1.6	0.20	B	8.00	----
7	Paper Phenolic (PP)	1/32	1	1.6	2.20	B	9.52	1101
8	Paper Phenolic (PP)	1/32	1	1.6	8.20	B	12.00	----
9	Paper Phenolic (PP)	1/32	1	1.6	14.90	B	17.10	----
10	Paper Phenolic (PP)	1/32	1	1.6	6.60	B	13.00	1101
11	Paper Phenolic (PP)	1/32	1	1.4	0.20	C	10.00	----

TABLE XXXIII (CONT)

PEEL STRENGTH TEST RESULTS AFTER SOLDER DIP AND CHEMICAL ETCHING OF PAPER PHENOLIC (1/32 INCH THICKNESS - 1 OZ. COPPER)

Spec. No.	Base Laminate	Laminate Thickness (Inch)	Copper Weight (Oz.)	Copper Foil Thickness Inch (10^{-3})	Solder Film Thickness Inch (10^{-3})	Manufacturer	Peel Strength After Dip Solder (Lbs/In. Width)	Chemical Etching Solution No.
12	Paper Phenolic (PP)	1/32	1	1.4	4.10	C	12.50	----
13	Paper Phenolic (PP)	1/32	1	1.4	5.10	C	14.00	1101
14	Paper Phenolic (PP)	1/32	1	1.7	7.80	C	18.00	1101
15	Paper Phenolic (PP)	1/32	1	1.7	3.20	C	11.00	----

TABLE XXXIV

PEEL STRENGTH TEST RESULTS AFTER SOLDER DIP AND CHEMICAL ETCHING OF PAPER PHENOLIC (1/32 INCH THICKNESS - 2 OZ.COPPER)

Spec. No.	Base Laminate	Laminate Thickness (Inch)	Copper Weight (Oz.)	Copper Foil Thickness Inch (10^{-3})	Solder Film Thickness Inch (10^{-3})	Manufacturer	Peel Strength After Dip Solder (Lbs/In. Width)	Chemical Etching Solution No.
16	Paper Phenolic (PP)	1/32	2	3.5	0.50	A	16.00	----
17	Paper Phenolic (PP)	1/32	2	3.5	2.80	A	17.00	1101
18	Paper Phenolic (PP)	1/32	2	3.5	12.50	A	18.80	----
19	Paper Phenolic (PP)	1/32	2	3.5	14.70	A	18.00	1101
20	Paper Phenolic (PP)	1/32	2	3.5	4.90	A	18.00	1101
21	Paper Phenolic (PP)	1/32	2	3.1	0.20	B	14.00	----
22	Paper Phenolic (PP)	1/32	2	3.1	4.00	B	14.00	1101
23	Paper Phenolic (PP)	1/32	2	3.1	8.80	B	16.50	1101
24	Paper Phenolic (PP)	1/32	2	3.1	3.80	B	14.90	----
25	Paper Phenolic (PP)	1/32	2	3.1	7.00	B	15.40	----
26	Paper Phenolic (PP)	1/32	2	3.6	0.10	C	12.80	----

TABLE XXXIV (CONT)

PEEL STRENGTH TEST RESULTS AFTER SOLDER DIP AND CHEMICAL ETCHING OF PAPER PHENOLIC (1 32 INCH THICKNESS - 2 OZ.COPPER)

Spec. No.	Base Laminate	Laminate Thickness (Inch)	Copper Weight (Oz.)	Copper Foil Thickness Inch (10^{-3})	Solder Film Thickness Inch (10^{-3})	Manufacturer	Peel Strength After Dip Solder (Lbs/In. Width)	Chemical Etching Solution No.
27	Paper Phenolic (PP)	1/32	2	3.6	11.40	C	16.00	1101
28	Paper Phenolic (PP)	1/32	2	3.6	0.60	C	14.00	1101
29	Paper Phenolic (PP)	1/32	2	3.6	2.90	C	14.00	----
30	Paper Phenolic (PP)	1/32	2	3.6	4.90	C	14.00	1101

TABLE XXXV

PEEL STRENGTH TEST RESULTS AFTER SOLDER DIP AND CHEMICAL ETCHING OF PAPER PHENOLIC (1/8 INCH THICKNESS 1 OZ. COPPER)

Spec. No.	Base Laminate	Laminate Thickness (Inch)	Copper Weight (Oz.)	Copper Foil Thickness Inch (10^{-3})	Solder Film Thickness Inch (10^{-3})	Manufacturer	Peel Strength After Dip Solder (Lbs/In. Width)	Chemical Etching Solution No.
31	Paper Phenolic (PP)	1/8	1	1.5	2.80	A	11.00	----
32	Paper Phenolic (PP)	1/8	1	1.5	0.24	A	9.75	1101
33	Paper Phenolic (PP)	1/8	1	1.5	7.80	A	15.84	1101
34	Paper Phenolic (PP)	1/8	1	1.5	9.25	A	16.00	1101
35	Paper Phenolic (PP)	1/8	1	1.5	14.00	A	15.34	----
36	Paper Phenolic (PP)	1/8	1	1.4	1.90	B	7.50	----
37	Paper Phenolic (PP)	1/8	1	1.4	5.20	B	12.00	----
38	Paper Phenolic (PP)	1/8	1	1.4	10.90	B	16.90	1101
39	Paper Phenolic (PP)	1/8	1	1.4	8.60	B	16.00	1101
40	Paper Phenolic (PP)	1/8	1	1.4	7.60	B	16.00	1101
41	Paper Phenolic (PP)	1/8	1	1.7	0.30	C	9.20	----

TABLE XXXV (CONT)

PEEL STRENGTH TEST RESULTS AFTER SOLDER DIP AND CHEMICAL ETCHING OF PAPER PHENOLIC (1/8 INCH THICKNESS 1 OZ. COPPER)

Spec. No.	Base Laminate	Laminate Thickness (Inch)	Copper Weight (Oz.)	Copper Foil Thickness Inch (10^{-3})	Solder Film Thickness Inch (10^{-3})	Manufacturer	Peel Strength After Dip Solder (Lbs/In. Width)	Chemical Etching Solution No.
42	Paper Phenolic (PP)	1/8	1	1.7	0.60	C	9.00	1101
43	Paper Phenolic (PP)	1/8	1	1.7	2.70	C	12.00	1101
44	Paper Phenolic (PP)	1/8	1	1.7	13.00	C	16.10	----
45	Paper Phenolic (PP)	1/8	1	1.7	7.80	C	18.00	1101

TABLE XXXVI

PEEL STRENGTH TEST RESULTS AFTER SOLDER DIP AND CHEMICAL ETCHING OF PAPER PHENOLIC (1/8 INCH THICKNESS 2 OZ. COPPER)

Spec. No.	Base Laminate	Laminate Thickness (Inch)	Copper Weight (Oz.)	Copper Foil Thickness Inch (10^{-3})	Solder Film Thickness Inch (10^{-3})	Manufacturer	Peel Strength After Dip Solder (Lbs/In. Width)	Chemical Etching Solution No.
46	Paper Phenolic (PP)	1/8	2	3.5	0.20	A	17.00	----
47	Paper Phenolic (PP)	1/8	2	3.5	3.80	A	22.00	1101
48	Paper Phenolic (PP)	1/8	2	3.5	5.80	A	20.00	----
49	Paper Phenolic (PP)	1/8	2	3.5	7.30	A	22.00	1101
50	Paper Phenolic (PP)	1/8	2	3.5	9.00	A	19.50	1101
51	Paper Phenolic (PP)	1/8	2	2.9	0.20	B	14.50	----
52	Paper Phenolic (PP)	1/8	2	2.9	4.00	B	16.00	1101
53	Paper Phenolic (PP)	1/8	2	2.9	8.20	B	20.00	----
54	Paper Phenolic (PP)	1/8	2	2.9	10.00	B	20.50	1101
55	Paper Phenolic (PP)	1/8	2	2.9	16.50	B	20.00	1101
56	Paper Phenolic (PP)	1/8	2	3.0	0.4	C	12.00	----

TABLE XXXVI (CONT)

PEEL STRENGTH TEST RESULTS AFTER SOLDER DIP AND CHEMICAL ETCHING OF PAPER PHENOLIC (1/8 INCH THICKNESS 2 OZ. COPPER)

Spec. No.	Base Laminate	Laminate Thickness (Inch)	Copper Weight (Oz.)	Copper Foil Thickness Inch (10^{-3})	Solder Film Thickness Inch (10^{-3})	Manufacturer	Peel Strength After Dip Solder (Lbs/In. Width)	Chemical Etching Solution No.
57	Paper Phenolic (PP)	1/8	2	3.0	8.6	C	18.40	----
58	Paper Phenolic (PP)	1/8	2	3.0	11.6	C	17.00	1101
59	Paper Phenolic (PP)	1/8	2	3.0	1.7	C	12.50	1101
60	Paper Phenolic (PP)	1/8	2	2.5	7.1	C	17.00	----

TABLE XXXVII

PEEL STRENGTH TEST RESULTS AFTER SOLDER DIP AND CHEMICAL ETCHING OF PAPER EPOXY (1/32 INCH THICKNESS - 1 OZ.COPPER)

Spec. No.	Base Laminate	Laminate Thickness (Inch)	Copper Weight (Oz.)	Copper Foil Thickness Inch (10^{-3})	Solder Film Thickness Inch (10^{-3})	Manufacturer	Peel Strength After Dip Solder (Lbs/In. Width)	Chemical Etching Solution No.
61	Paper Epoxy (PX)	1/32	1	1.4	0.50	A	7.50	----
62	Paper Epoxy (PX)	1/32	1	1.4	2.20	A	12.00	----
63	Paper Epoxy (PX)	1/32	1	1.4	3.50	A	9.00	1101
64	Paper Epoxy (PX)	1/32	1	1.4	3.00	A	8.47	1101
65	Paper Epoxy (PX)	1/32	1	1.4	10.00	A	13.00	----
66	Paper Epoxy (PX)	1/32	1	1.6	0.20	B	10.00	1101
67	Paper Epoxy (PX)	1/32	1	1.6	0.80	B	11.20	1101
68	Paper Epoxy (PX)	1/32	1	1.6	5.70	B	11.00	1101
69	Paper Epoxy (PX)	1/32	1	1.6	9.80	B	12.90	----
70	Paper Epoxy (PX)	1/32	1	1.6	13.00	B	13.46	1101
71	Paper Epoxy (PX)	1/32	1	1.7	0.10	D	11.50	----

TABLE XXXVII (CONT)

PEEL STRENGTH TEST RESULTS AFTER SOLDER DIP AND CHEMICAL ETCHING OF PAPER EPOXY (1/32 INCH THICKNESS - 1 OZ.COPPER)

Spec. No.	Base Laminate	Laminate Thickness (Inch)	Copper Weight (Oz.)	Copper Foil Thickness Inch (10^{-3})	Solder Film Thickness Inch (10^{-3})	Manufacturer	Peel Strength After Dip Solder (Lbs/In. Width)	Chemical Etching Solution No.
72	Paper Epoxy (PX)	1/32	1	1.7	0.20	D	10.00	1101
73	Paper Epoxy (PX)	1/32	1	1.7	4.00	D	15.50	1101
74	Paper Epoxy (PX)	1/32	1	1.7	7.60	D	20.00	1101
75	Paper Epoxy (PX)	1/32	1	1.7	10.80	D	24.0	----

TABLE XXXVIII

PEEL STRENGTH TEST RESULTS AFTER SOLDER DIP AND CHEMICAL ETCHING OF PAPER EPOXY (1 32 INCH THICKNESS - 2 OZ. COPPER)

Spec. No.	Base Laminate	Laminate Thickness (Inch)	Copper Weight (Oz.)	Copper Foil Thickness Inch (10^{-3})	Solder Film Thickness Inch (10^{-3})	Manufacturer	Peel Strength After Dip Solder (Lbs/In. Width)	Chemical Etching Solution No.
76	Paper Epoxy (PX)	1/32	2	2.8	0.10	A	16.00	----
77	Paper Epoxy (PX)	1/32	2	2.8	2.20	A	9.16	1101
78	Paper Epoxy (PX)	1/32	2	2.8	5.20	A	18.00	1101
79	Paper Epoxy (PX)	1/32	2	2.8	11.20	A	25.00	----
80	Paper Epoxy (PX)	1/32	2	2.8	12.00	A	25.10	----
81	Paper Epoxy (PX)	1/32	2	2.7	0.20	B	14.00	1101
82	Paper Epoxy (PX)	1/32	2	2.7	0.50	B	14.90	----
83	Paper Epoxy (PX)	1/32	2	2.7	6.80	B	16.00	----
84	Paper Epoxy (PX)	1/32	2	2.7	10.00	B	19.00	1101
85	Paper Epoxy (PX)	1/32	2	2.7	16.00	B	18.40	----
86	Paper Epoxy (PX)	1/32	2	2.8	0.20	D	15.40	----

TABLE XXXVIII (CONT)

PEEL STRENGTH TEST RESULTS AFTER SOLDER DIP AND CHEMICAL ETCHING OF PAPER EPOXY (1/32 INCH THICKNESS - 2 OZ. COPPER)

Spec. No.	Base Laminate	Laminate Thickness (Inch)	Copper Weight (Oz.)	Copper Foil Thickness Inch (10^{-3})	Solder Film Thickness Inch (10^{-3})	Manufacturer	Peel Strength After Dip Solder (Lbs/In. Width)	Chemical Etching Solution No.
87	Paper Epoxy (PX)	1/32	2	2.8	1.04	D	15.95	1101
88	Paper Epoxy (PX)	1/32	2	2.8	6.80	D	18.34	1101
89	Paper Epoxy (PX)	1/32	2	2.8	10.50	D	20.12	----
90	Paper Epoxy (PX)	1/32	2	2.8	13.00	D	22.45	1101

TABLE XXXIX

PEEL STRENGTH TEST RESULTS AFTER SOLDER DIP AND CHEMICAL ETCHING OF PAPER EPOXY (1/8 INCH THICKNESS - 1 OZ.COPPER)

Spec. No.	Base Laminate	Laminate Thickness (Inch)	Copper Weight (Oz.)	Copper Foil Thickness Inch (10^{-3})	Solder Film Thickness Inch (10^{-3})	Manufacturer	Peel Strength After Dip Solder (Lbs/In. Width)	Chemical Etching Solution No.
91	Paper Epoxy (PX)	1/8	1	1.6	0.10	A	12.50	1101
92	Paper Epoxy (PX)	1/8	1	1.6	1.30	A	13.00	----
93	Paper Epoxy (PX)	1/8	1	1.6	3.70	A	12.40	1101
94	Paper Epoxy (PX)	1/8	1	1.6	9.70	A	19.70	1101
95	Paper Epoxy (PX)	1/8	1	1.6	15.10	A	24.00	----
96	Paper Epoxy (PX)	1/8	1	1.7	0.10	B	10.50	----
97	Paper Epoxy (PX)	1/8	1	1.7	0.40	B	9.53	1101
98	Paper Epoxy (PX)	1/8	1	1.7	5.60	B	17.00	----
99	Paper Epoxy (PX)	1/8	1	1.7	6.80	B	16.50	1101
100	Paper Epoxy (PX)	1/8	1	1.7	13.30	B	22.00	1101
101	Paper Epoxy (PX)	1/8	1	1.4	0.50	D	10.50	----

TABLE XXXIX (CONT)

PEEL STRENGTH TEST RESULTS AFTER SOLDER DIP AND CHEMICAL ETCHING OF PAPER EPOXY
(1/8 INCH THICKNESS - 1 OZ. COPPER)

Spec. No.	Base Laminate	Laminate Thickness (Inch)	Copper Weight (Oz.)	Copper Foil Thickness Inch (10^{-3})	Solder Film Thickness Inch (10^{-3})	Manufacturer	Peel Strength After Dip Solder (Lbs/In. Width)	Chemical Etching Solution No.
102	Paper Epoxy (PX)	1/8	1	1.4	2.30	D	10.00	1101
103	Paper Epoxy (PX)	1/8	1	1.4	11.10	D	20.00	----
104	Paper Epoxy (PX)	1/8	1	1.4	17.30	D	23.5	1101
105	Paper Epoxy (PX)	1/8	1	1.4	10.00	D	18.00	1101

TABLE XL

PEEL STRENGTH TEST RESULTS AFTER SOLDER DIP AND CHEMICAL ETCHING OF PAPER EPOXY (1 8 INCH THICKNESS - 2 OZ. COPPER)

Spec. No.	Base Laminate	Laminate Thickness (Inch)	Copper Weight (Oz.)	Copper Foil Thickness Inch (10^{-3})	Solder Film Thickness Inch (10^{-3})	Manufacturer	Peel Strength After Dip Solder (Lbs/In. Width)	Chemical Etching Solution No.
106	Paper Epoxy (PX)	1/8	2	2.8	0.10	A	14.50	----
107	Paper Epoxy (PX)	1/8	2	2.8	2.25	A	10.00	1101
108	Paper Epoxy (PX)	1/8	2	2.8	6.40	A	17.25	----
109	Paper Epoxy (PX)	1/8	2	2.8	12.00	A	23.00	1101
110	Paper Epoxy (PX)	1/8	2	2.8	14.00	A	24.80	1101
111	Paper Epoxy (PX)	1/8	2	2.7	0.20	B	13.50	----
112	Paper Epoxy (PX)	1/8	2	2.7	7.00	B	17.00	1101
113	Paper Epoxy (PX)	1/8	2	2.7	11.40	B	20.10	1101
114	Paper Epoxy (PX)	1/8	2	2.7	15.45	B	19.84	----
115	Paper Epoxy (PX)	1/8	2	2.7	13.60	B	18.40	----
116	Paper Epoxy (PX)	1/8	2	2.8	0.30	D	15.85	1101

TABLE XL (CONT)

PEEL STRENGTH TEST RESULTS AFTER SOLDER DIP AND CHEMICAL ETCHING OF PAPER EPOXY (1/8 INCH THICKNESS - 2 OZ.COPPER)

Spec. No.	Base Laminate	Laminate Thickness (Inch)	Copper Weight (Oz.)	Copper Foil Thickness Inch (10^{-3})	Solder Film Thickness Inch (10^{-3})	Manufacturer	Peel Strength After Dip Solder (Lbs/In. Width	Chemical Etching Solution No.
117	Paper Epoxy (PX)	1/8	2	2.8	2.00	D	16.08	----
118	Paper Epoxy (PX)	1/8	2	2.8	7.04	D	18.75	----
119	Paper Epoxy (PX)	1/8	2	2.8	10.00	D	21.00	1101
120	Paper Epoxy (PX)	1/8	2	2.8	15.00	D	23.00	1101

TABLE XLI

PEEL STRENGTH TEST RESULTS AFTER SOLDER DIP AND CHEMICAL ETCHING OF GLASS EPOXY - GE
(1 8 INCH THICKNESS 1 OZ.COPPER)

Spec. No.	Base Laminate	Laminate Thickness (Inch)	Copper Weight (Oz.)	Copper Foil Thickness Inch (10^{-3})	Solder Film Thickness Inch (10^{-3})	Manufacturer	Peel Strength After Dip Solder (Lbs/In. Width)	Chemical Etching Solution No.
121	Glass Epoxy (GE)	1/8	1	1.5	0.10	A	7.50	----
122	Glass Epoxy (GE)	1/8	1	1.5	3.30	A	11.50	----
123	Glass Epoxy (GE)	1/8	1	1.5	5.80	A	12.50	1101
124	Glass Epoxy (GE)	1/8	1	1.3	11.90	A	18.00	1101
125	Glass Epoxy (GE)	1/8	1	1.6	0.20	B	9.00	----
126	Glass Epoxy (GE)	1/8	1	1.6	3.34	B	11.00	1101
127	Glass Epoxy (GE)	1/8	1	1.6	7.80	B	16.34	1101
128	Glass Epoxy (GE)	1/8	1	1.6	11.00	B	13.75	----
129	Glass Epoxy (GE)	1/8	1	1.4	0.50	C	11.50	----
130	Glass Epoxy (GE)	1/8	1	1.4	7.90	C	20.00	1101
131	Glass Epoxy (GE)	1/8	1	1.4	7.50	C	20.50	1101
132	Glass Epoxy (GE)	1/8	1	1.4	9.60	C	23.90	----

TABLE XLII

PEEL STRENGTH TEST RESULTS AFTER SOLDER DIP AND CHEMICAL ETCHING OF GLASS EPOXY - GE (1/8 INCH THICKNESS 2 OZ.COPPER)

Spec. No.	Base Laminate	Laminate Thickness (Inch)	Copper Weight (Oz.)	Copper Foil Thickness Inch (10^{-3})	Copper Film Thickness Inch (10^{-3})	Manufacturer	Peel Strength After Dip Solder (Lbs/In. Width)	Chemical Etching Solution No.
133	Glass Epoxy (GE)	1/8	2	2.6	1.20	A	17.40	----
134	Glass Epoxy (GE)	1/8	2	2.6	2.00	A	18.00	1101
135	Glass Epoxy (GE)	1/8	2	2.6	6.40	A	10.90	1101
136	Glass Epoxy (GE)	1/8	2	2.6	14.70	A	28.00	----
137	Glass Epoxy (GE)	1/8	2	2.6	0.40	B	16.50	----
138	Glass Epoxy (GE)	1/8	2	2.6	4.70	B	24.00	1101
139	Glass Epoxy (GE)	1/8	2	2.6	18.80	B	28.00	1101
140	Glass Epoxy (GE)	1/8	2	2.6	16.40	B	24.80	----
141	Glass Epoxy (GE)	1/8	2	2.4	0.40	C	18.00	----
142	Glass Epoxy (GE)	1/8	2	2.4	8.90	C	31.20	1101
143	Glass Epoxy (GE)	1/8	2	2.4	9.00	C	28.00	----
144	Glass Epoxy (GE)	1/8	2	2.4	11.00	C	27.00	1101

TABLE XLIII

PEEL STRENGTH TEST RESULTS AFTER SOLDER DIP AND CHEMICAL ETCHING OF GLASS EPOXY - GB (1/8 INCH THICKNESS - 1 OZ. COPPER)

Spec. No.	Base Laminate	Laminate Thickness (Inch)	Copper Weight (Oz.)	Copper Foil Thickness Inch (10^{-3})	Solder Film Thickness Inch (10^{-3})	Manufacturer	Peel Strength After Dip Solder (Lbs/In. Width)	Chemical Etching Solution No.
145	Glass Epoxy (GB)	1/8	1	1.8	0.80	A	10.90	----
146	Glass Epoxy (GB)	1/8	1	1.8	5.30	A	12.50	1101
147	Glass Epoxy (GB)	1/8	1	1.8	6.00	A	12.00	1101
148	Glass Epoxy (GB)	1/8	1	1.8	10.40	A	16.00	----
149	Glass Epoxy (GB)	1/8	1	1.6	0.30	B	9.00	----
150	Glass Epoxy (GB)	1/8	1	1.6	2.44	B	10.50	1101
151	Glass Epoxy (GB)	1/8	1	1.6	7.25	B	14.25	1101
152	Glass Epoxy (GB)	1/8	1	1.6	12.00	B	16.10	----
153	Glass Epoxy (GB)	1/8	1	1.7	0.50	C	11.50	1101
154	Glass Epoxy (GB)	1/8	1	1.7	4.80	C	12.45	----
155	Glass Epoxy (GB)	1/8	1	1.7	10.14	C	16.40	1101
156	Glass Epoxy (GB)	1/8	1	1.7	14.00	C	18.75	----

TABLE XLIV

PEEL STRENGTH TEST RESULTS AFTER SOLDER DIP AND CHEMICAL ETCHING OF GLASS EPOXY - GB (1/8 INCH THICKNESS 2 OZ. COPPER)

Spec. No.	Base Laminate	Laminate Thickness (Inch)	Copper Weight (Oz.)	Copper Foil Thickness Inch (10^{-3})	Solder Film Thickness Inch (10^{-3})	Manufacturer	Peel Strength After Dip Solder (Lbs/In. Width)	Chemical Etching Solution No.
157	Glass Epoxy (GB)	1/8	2	2.5	0.10	A	14.10	----
158	Glass Epoxy (GB)	1/8	2	2.5	3.45	A	16.00	1101
159	Glass Epoxy (GB)	1/8	2	2.5	8.00	A	19.75	1101
160	Glass Epoxy (GB)	1/8	2	2.5	14.00	A	23.36	----
161	Glass Epoxy (GB)	1/8	2	2.7	0.30	B	15.50	----
162	Glass Epoxy (GB)	1/8	2	2.7	2.25	B	16.24	1101
163	Glass Epoxy (GB)	1/8	2	2.7	10.10	B	19.36	1101
164	Glass Epoxy (GB)	1/8	2	2.7	16.00	B	24.25	----
165	Glass Epoxy (GB)	1/8	2	2.8	0.20	C	15.75	----
166	Glass Epoxy (GB)	1/8	2	2.8	6.25	C	19.04	1101
167	Glass Epoxy (GB)	1/8	2	2.8	10.50	C	22.14	----
168	Glass Epoxy (GB)	1/8	2	2.8	17.25	C	26.00	1101

TABLE XLV

PEEL STRENGTH TEST RESULTS AFTER SOLDER DIP AND CHEMICAL ETCHING OF GLASS EPOXY - GF
(1/8 INCH THICKNESS 1 OZ. COPPER)

Spec. No.	Base Laminate	Laminate Thickness (Inch)	Copper Weight (Oz.)	Copper Foil Thickness Inch (10^{-3})	Solder Film Thickness Inch (10^{-3})	Manufacturer	Peel Strength After Dip Solder (Lbs/In. Width)	Chemical Etching Solution No.
169	Glass Epoxy (GF)	1/8	1	1.2	0.60	A	8.00	----
170	Glass Epoxy (GF)	1/8	1	1.2	7.90	A	14.00	----
171	Glass Epoxy (GF)	1/8	1	1.2	5.80	A	12.50	1101
172	Glass Epoxy (GF)	1/8	1	1.2	10.00	A	16.00	1101
173	Glass Epoxy (GF)	1/8	1	1.4	0.10	B	10.00	----
174	Glass Epoxy (GF)	1/8	1	1.4	1.90	B	11.50	1101
175	Glass Epoxy (GF)	1/8	1	1.4	7.50	B	13.90	----
176	Glass Epoxy (GF)	1/8	1	1.4	11.00	B	19.40	1101
177	Glass Epoxy (GF)	1/8	1	1.2	0.50	C	10.00	1101
178	Glass Epoxy (GF)	1/8	1	1.2	1.20	C	11.50	----
179	Glass Epoxy (GF)	1/8	1	1.2	3.10	C	12.50	1101
180	Glass Epoxy (GF)	1/8	1	1.2	10.20	C	18.80	----

TABLE XLVI

PEEL STRENGTH TEST RESULTS AFTER SOLDER DIP AND CHEMICAL ETCHING OF GLASS EPOXY - GF (1/8 INCH THICKNESS 2 OZ.COPPER)

Spec. No.	Base Laminate	Laminate Thickness (Inch)	Copper Weight (Oz.)	Copper Foil Thickness Inch (10^{-3})	Solder Film Thickness Inch (10^{-3})	Manufacturer	Peel Strength After Dip Solder (Lbs/In. Width)	Chemical Etching Solution No.
181	Glass Epoxy (GF)	1/8	2	2.7	0.10	A	14.40	----
182	Glass Epoxy (GF)	1/8	2	2.7	2.05	A	15.05	1101
183	Glass Epoxy (GF)	1/8	2	2.7	7.30	A	18.75	1101
184	Glass Epoxy (GF)	1/8	2	2.7	11.40	A	21.60	----
185	Glass Epoxy (GF)	1/8	2	2.8	0.20	B	13.50	----
186	Glass Epoxy (GF)	1/8	2	2.8	2.00	B	14.00	1101
187	Glass Epoxy (GF)	1/8	2	2.8	3.00	B	15.50	1101
188	Glass Epoxy (GF)	1/8	2	2.8	2.60	B	16.00	----
189	Glass Epoxy (GF)	1/8	2	2.7	0.50	C	13.00	1101
190	Glass Epoxy (GF)	1/8	2	2.7	2.40	C	15.00	1101
191	Glass Epoxy (GF)	1/8	2	2.7	7.80	C	17.10	----
192	Glass Epoxy (GF)	1/8	2	2.7	13.00	C	22.00	----

TABLE XLVII

PEEL STRENGTH TEST RESULTS AFTER SOLDER DIP AND CHEMICAL ETCHING OF GLASS MELAMINE AND GLASS SILICONE (1/8 INCH THICKNESS - 1 OZ.COPPER)

Spec. No.	Base Laminate	Laminate Thickness (Inches)	Copper Weight (Oz.)	Copper Foil Thickness Inch (10^{-3})	Solder Film Thickness Inch (10^{-3})	Manufacturer	Peel Strength After Dip Solder (Lbs/In. Width)	Chemical Etching Solution No.
193	Glass Melamine (GM)	1/8	1	1.4	0.30	A	8.34	----
194	Glass Melamine (GM)	1/8	1	1.4	4.60	A	9.75	1101
195	Glass Melamine (GM)	1/8	1	1.4	9.40	A	13.40	1101
196	Glass Melamine (GM)	1/8	1	1.4	12.00	A	15.40	----
197	Glass Silicone (GS)	1/8	1	1.5	0.10	A	7.50	----
198	Glass Silicone (GS)	1/8	1	1.5	5.80	A	12.50	1101
199	Glass Silcone (GS)	1/8	1	1.5	3.30	A	11.50	----
200	Glass Silcone (GS)	1/8	1	1.5	11.00	A	16.00	1101

TABLE XLVIII

PEEL STRENGTH TEST RESULTS AFTER SOLDER DIP AND CHEMICAL ETCHING OF GLASS MELAMINE AND GLASS SILICONE (1/8 INCH THICKNESS - 2 OZ.COPPER)

Spec. No.	Base Laminate	Laminate Thickness (Inch)	Copper Weight (Oz.)	Copper Foil Thickness Inch (10^{-3})	Solder Film Thickness Inch (10^{-3})	Manufacturer	Peel Strength After Dip Solder (Lbs/In. Width)	Chemical Etching Solution No.
201	Glass Melamine (GM)	1/8	2	2.6	1.10	A	12.00	----
202	Glass Melamine (GM)	1/8	2	2.6	3.70	A	14.40	----
203	Glass Melamine (GM)	1/8	2	2.6	14.60	A	13.50	1101
204	Glass Melamine (GM)	1/8	2	2.6	12.20	A	12.00	1101
205	Glass Silicone (GS)	1/8	2	2.9	0.20	A	9.00	----
206	Glass Silicone (GS)	1/8	2	2.9	13.10	A	16.00	1101
207	Glass Silicone (GS)	1/8	2	2.9	2.10	A	9.50	----
208	Glass Silicone (GS)	1/8	2	2.9	11.50	A	14.00	1101

TABLE XLIX

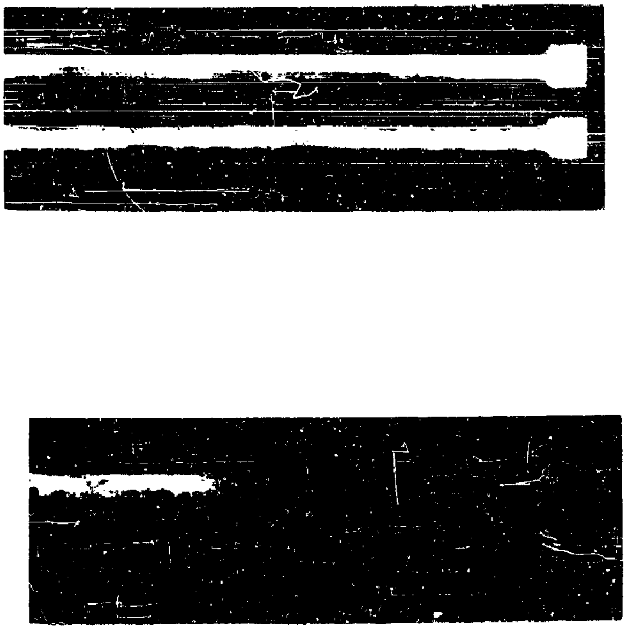
PEEL STRENGTH TEST RESULTS AFTER SOLDER DIP AND CHEMICAL ETCHING OF GLASS TEFLON (1 8 INCH THICKNESS - 1 OZ. COPPER)

Spec. No.	Base Laminate	Laminate Thickness (Inch)	Copper Weight (Oz.)	Copper Foil Thickness Inch (10-3)	Solder Film Thickness Inch (10^{-3}).	Manufacturer	Peel Strength After Dip Solder (Lbs/In. Width)	Chemical Etching Solution No.
209	Glass Teflon (GT)	1 8	1	1.8	0.90	B	7.45	----
210	Glass Teflon (GT)	1 8	1	1.8	3.20	B	9.00	1101
211	Glass Teflon (GT)	1/8	1	1.8	3.20	B	9.50	1101
212	Glass Teflon (GT)	1 8	1	1.8	9.80	B	23.00	----
213	Glass Teflon (GT)	1/8	1	1.5	0.10	E	2.48	----
214	Glass Teflon (GT)	1/8	1	1.5	3.50	E	8.47	1101
215	Glass Teflon (GT)	1 8	1	1.5	6.00	E	8.00	1101
216	Glass Teflon (GT)	1/8	1	1.5	9.50	E	11.50	----

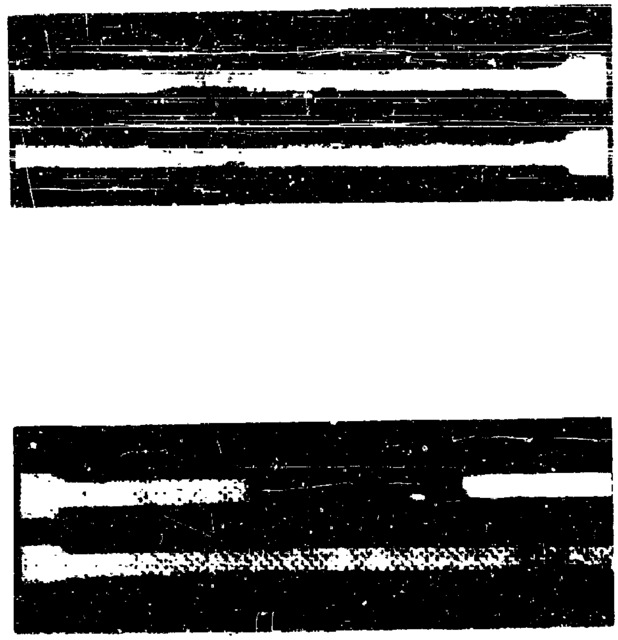
TABLE L

PEEL STRENGTH TEST RESULTS AFTER SOLDER DIP AND CHEMICAL ETCHING OF GLASS TEFLON (1/8 INCH THICKNESS - 2 OZ. COPPER)

Spec. No.	Base Laminate	Laminate Thickness (Inch)	Copper Weight (Oz.)	Copper Foil Thickness Inch (10^{-3})	Solder Film Thickness Inch (10^{-3})	Manufacturer	Peel Strength After Dip Solder (Lbs/In. Width)	Chemical Etching Solution No.
217	Glass Teflon (GT)	1/8	2	3.7	0.10	B	16.00	----
218	Glass Teflon (GT)	1/8	2	3.7	2.80	B	18.00	1101
219	Glass Teflon (GT)	1/8	2	3.7	3.80	B	18.00	1101
220	Glass Teflon (GT)	1/8	2	3.7	9.30	B	32.00	----
221	Glass Teflon (GT)	1/8	2	2.9	0.30	E	10.00	----
223	Glass Teflon (GT)	1/8	2	2.9	4.60	E	12.00	1101
224	Glass Teflon (GT)	1/8	2	2.9	6.60	E	12.00	1101
225	Glass Teflon (GT)	1/8	2	2.9	14.90	E	18.80	----



GLASS EPOXY-(GE)



GLASS MELAMINE-(GM)

Figure No. 63. Peel Strength Specimens After Solder Dip

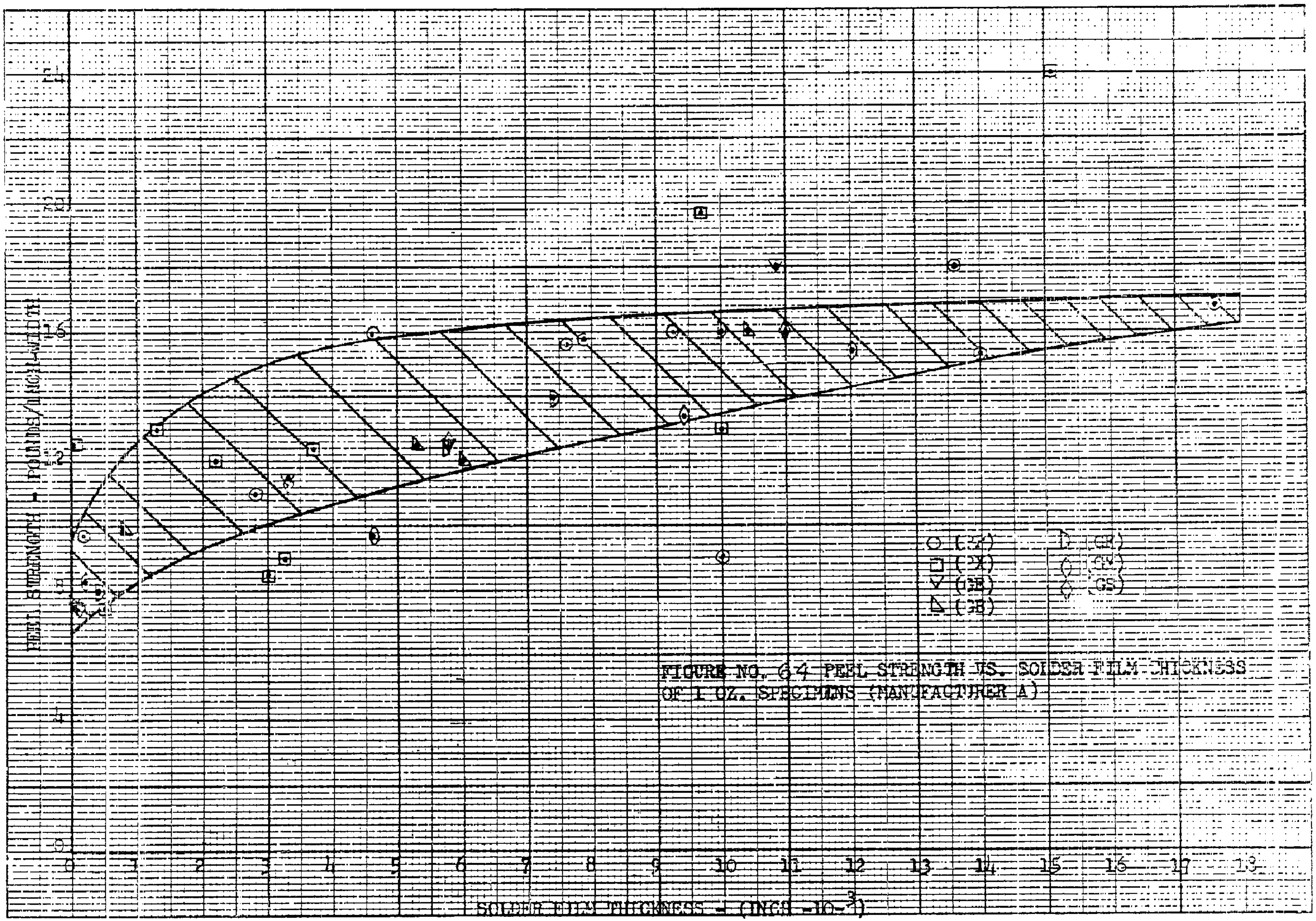


FIGURE NO. 6-4 PEEL STRENGTH VS. SOLDER FILM THICKNESS OF 1 OZ. SPECIMENS (MANUFACTURER A)

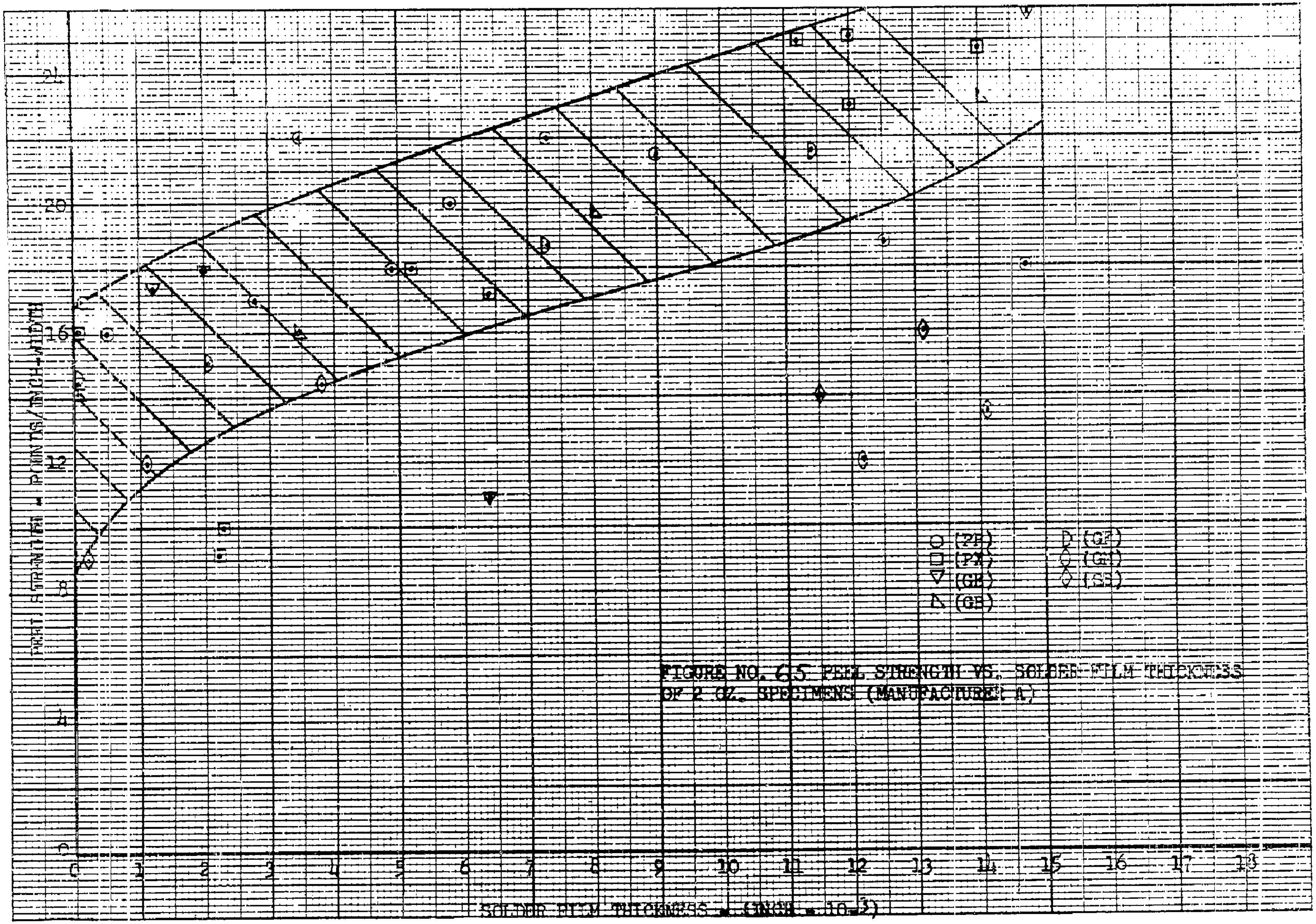


FIGURE NO. 65 PEEL STRENGTH VS. SOLDER FILM THICKNESS OF 2 OZ. SPECIMENS (MANUFACTURER A)

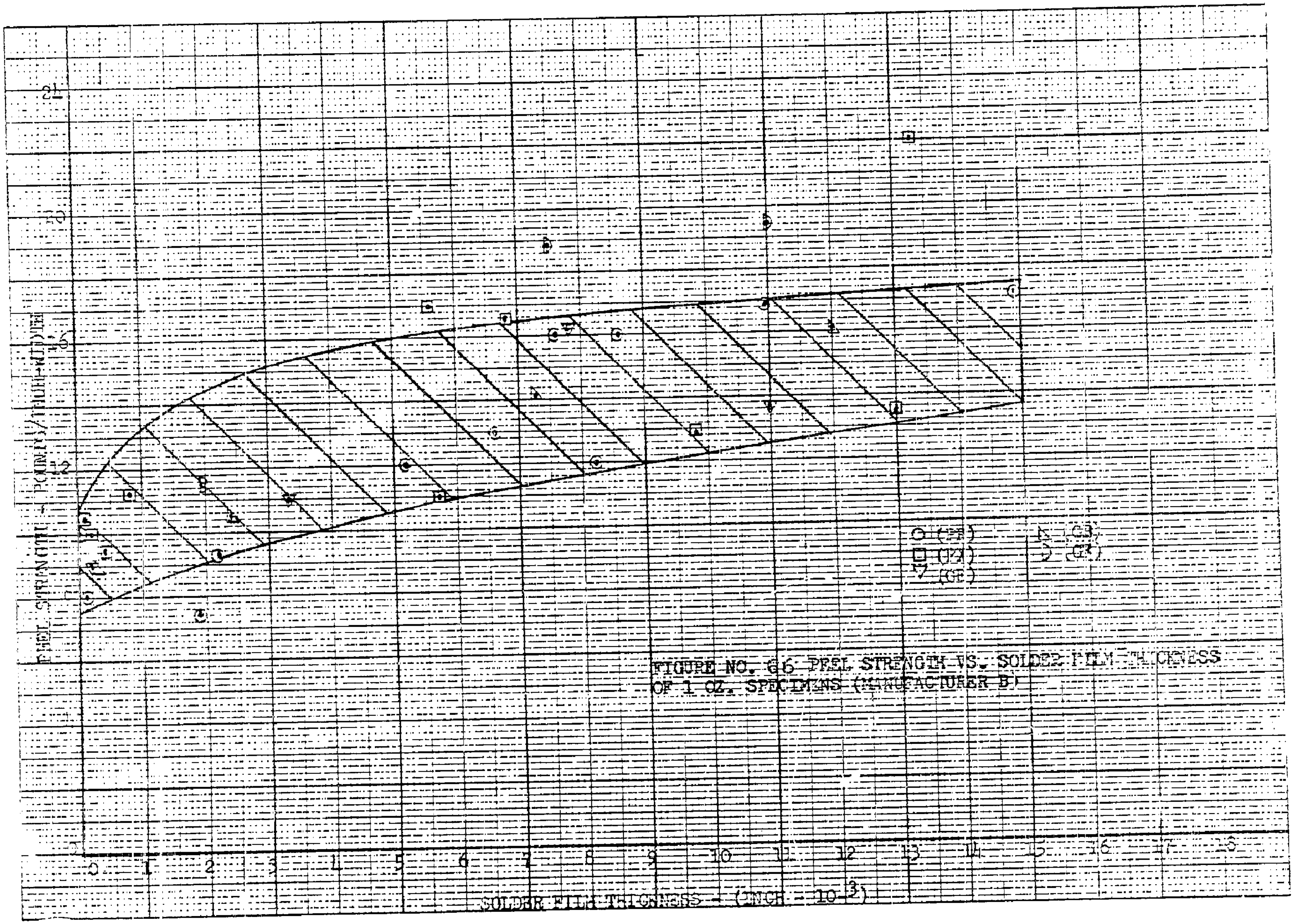


FIGURE NO. G6 PEEL STRENGTH VS. SOLDER FILM THICKNESS OF 1 OZ. SPECIMENS (MANUFACTURER B)

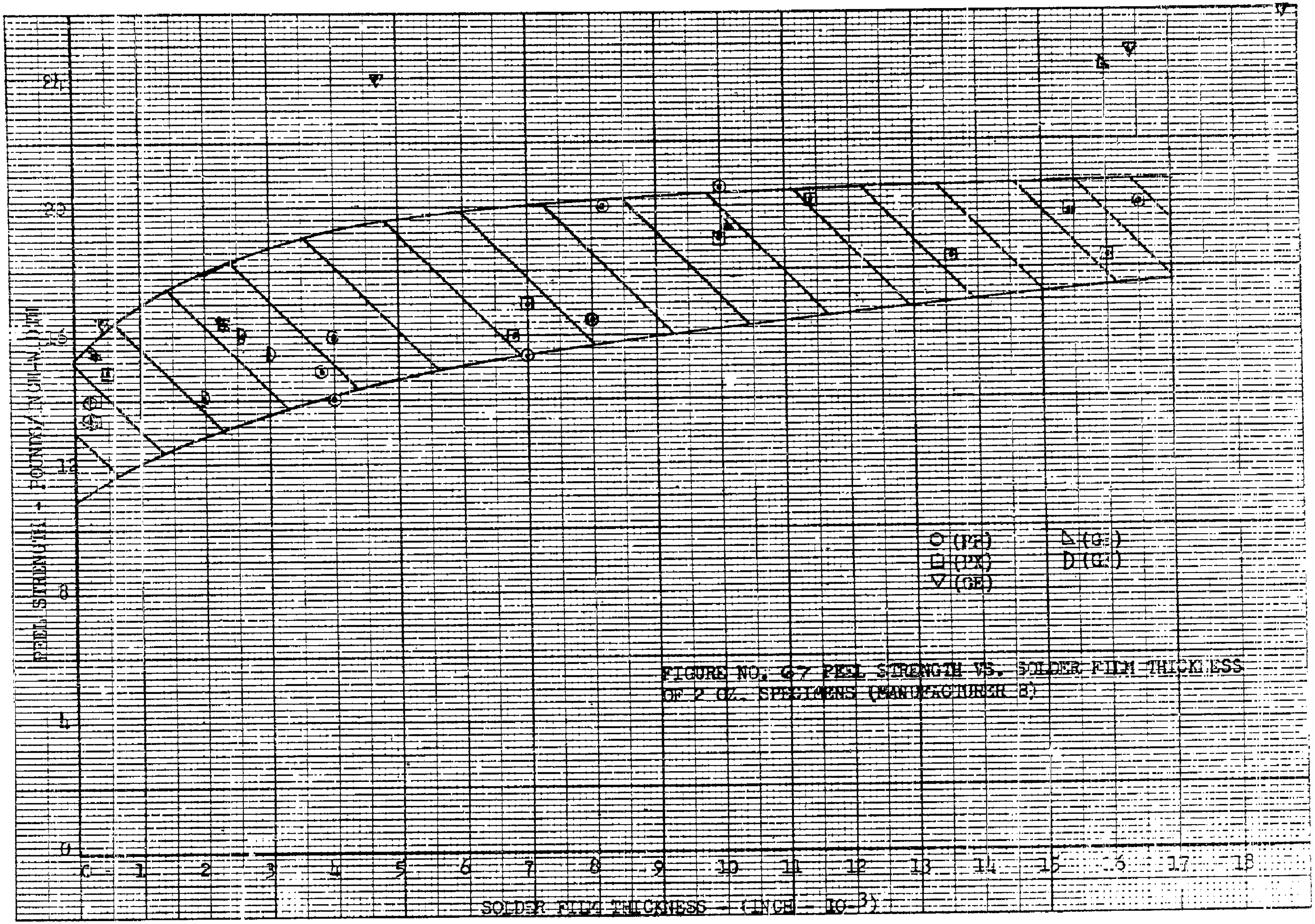


FIGURE NO. 67 PEEL STRENGTH VS. SOLDER FILM THICKNESS OF 2 OZ. SPECIMENS (MANUFACTURER B)

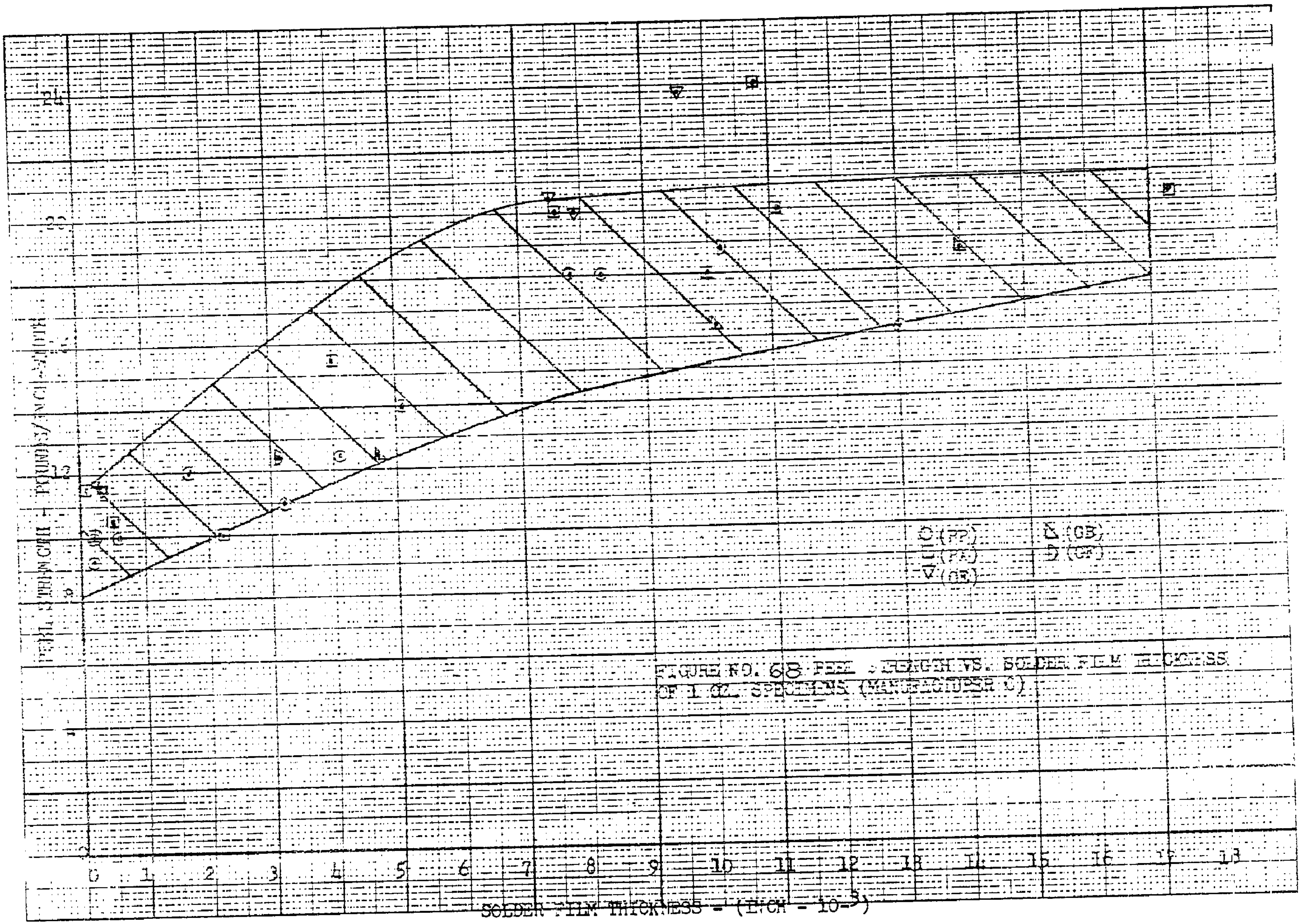


FIGURE NO. 68 PEEL STRENGTH VS. SOLDER FILM THICKNESS OF 1 OZ. SPECIMENS (MANUFACTURER C)

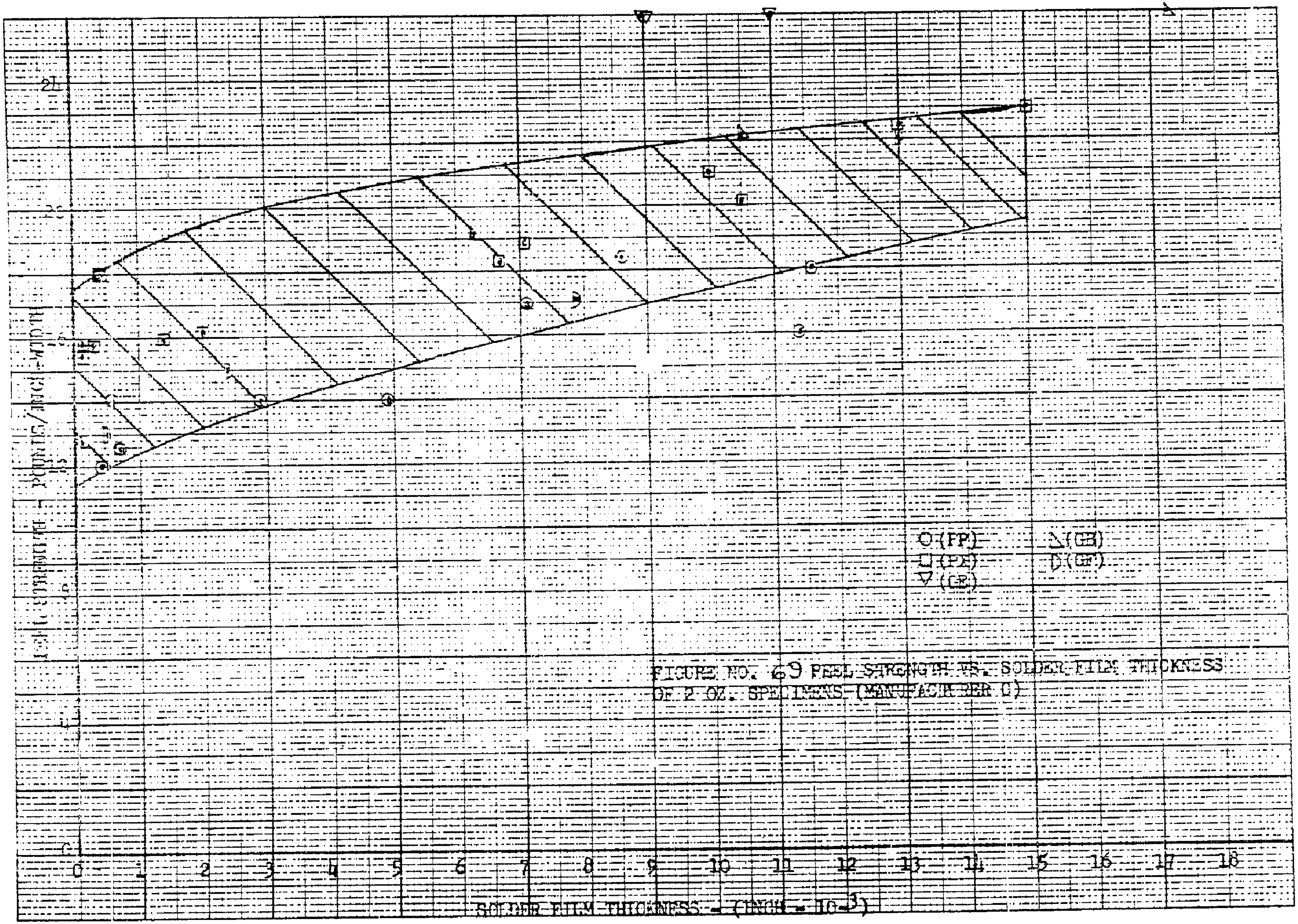
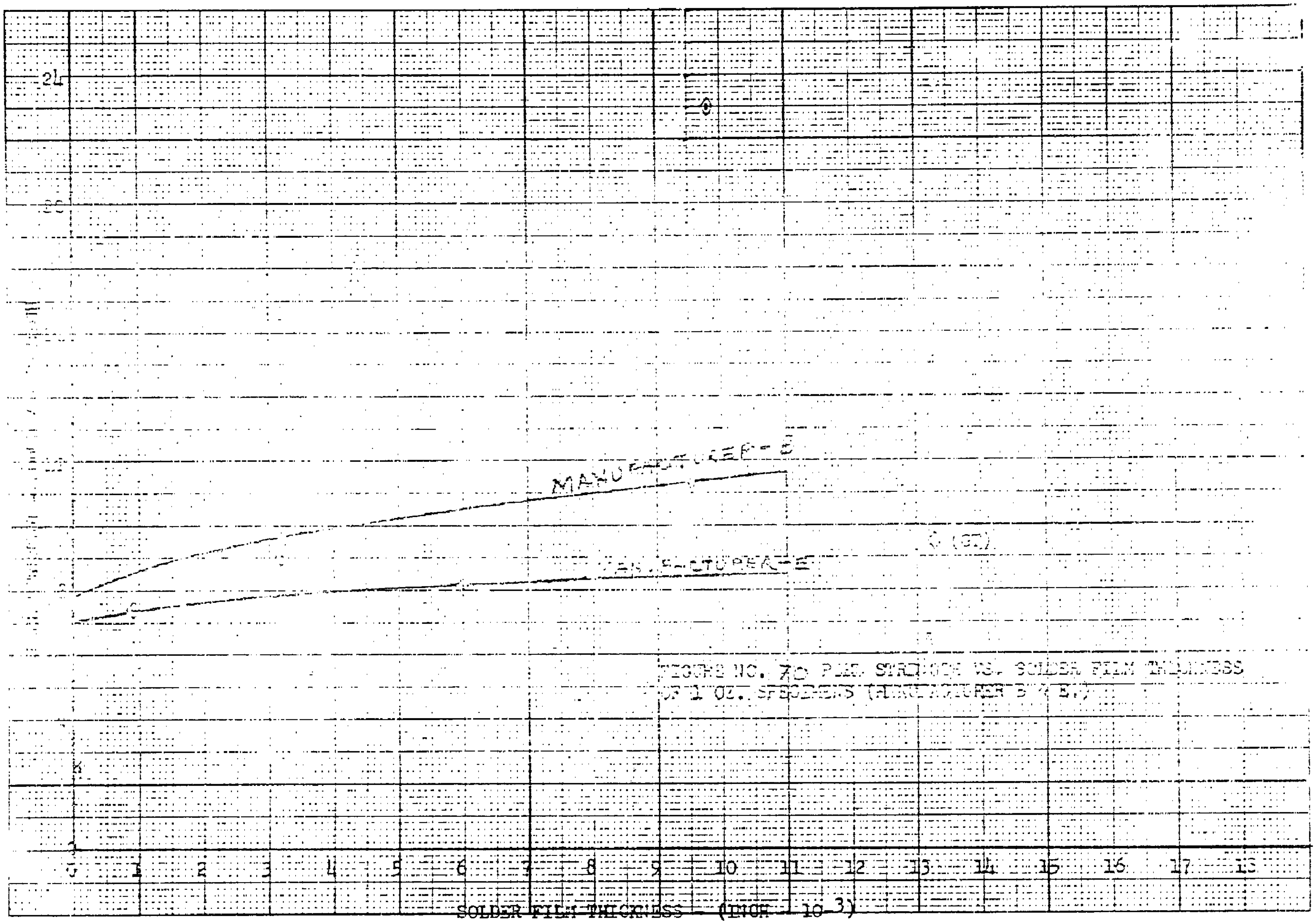
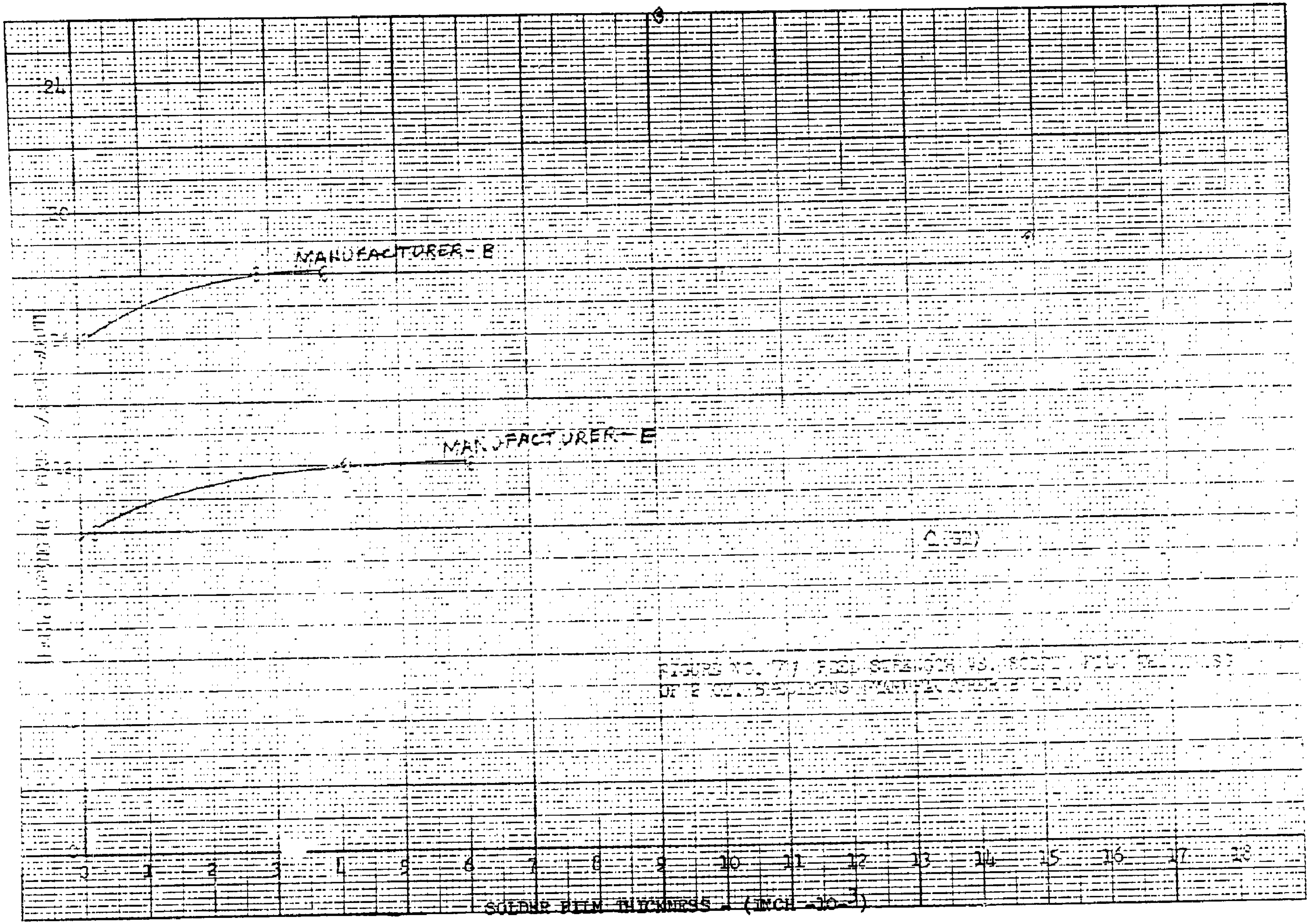


FIGURE NO. 69 PEEL STRENGTH VS. SOLDER FILM THICKNESS OF 2 OZ. SPECIMENS (MANUFACTURER C)



24
MANUFACTURER - B
MANUFACTURER - E
FIGURE NO. 70 ... VS. SOLDER FILM THICKNESS
OF 1 OZ. SPECIMENS
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
SOLDER FILM THICKNESS (INCH × 10-3)



MANUFACTURER-B
MANUFACTURER-E
FIGURE NO. 77 PEEL STRENGTH VS.
SOLDER FILM THICKNESS - (INCH - 10^-3)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
24

4.5 Conclusions

The following conclusions are based on test data performed and reported under this Task.

1. The original intent of this Task was to evaluate the reproducibility of results obtained on bond strength of copper foil after dip soldering. After evaluating the data obtained from more than 200 samples, the results are so scattered that it is only possible to state that the results reproduce in general, only to the extent that there is a consistent increase in bond strength with increase in thickness of solder film. This general increase probably results from two main factors (1) some additional curing of the bonding resin by the heat of the solder pot, and (2) an increased amount of force necessary to bend the extra layer of solder, while simultaneously separating the copper from the base laminate.

2. The wide scattering of results, not only within each range of solder thickness, but also for each type of material, thickness of material and weight of copper, undoubtedly stems from all or a combination of the following factors:

   (1) Variations in laminating conditions of the original material.

   (2) Localized variation in thickness of the copper foil.

   (3) Localized variation in thickness of the solder film.

   (4) Variation in additional cure of bonding resin generated by (2) and (3) above.

   (5) Minor variations in test procedure.

5. Task D - Peel Strength at Elevated Temperature

5.1 Approach

To perform peel strength tests at specified elevated temperatures in accordance with test method specified in MIL-P-13949B. The basic test chamber design and specimen fabrication is discussed. The peel strength test results are reported and an analysis of the data made in the following pages.

5.2 Specimen Preparation

The peel strength test pattern was made as specified in MIL-P-13949B and the base materials are the same as specified in MIL-P-13949B. Two additional base materials (not specified in MIL-P-13949B) are included in the peel strength testing, paper epoxy and glass teflon. Specimens were 1" x 3" x 1/32" thick and 1" x 3" x 1/8" thick (pattern per MIL-P-13949B) for all materials. One set of specimens had one oz. copper on one side and another set of five specimens had two oz. copper on one side. Five specimens for each type material from at least three manufacturers were tested for each condition.

The test specimens were processed according to the procedure set forth in Appendix B at the back of the report.

5.3 Design of High Temperature Test Chamber

Figure No. 72 shows the completed high temperature peel strength test chamber. The metal chamber is lined with 1/4 inch asbestos board and equipped with a tempered glass in the door as shown in Figure No. 72. The two aluminum blocks (see Figure No. 72) are part of the test specimen fixture which holds the specimen in position during the peel test. Not

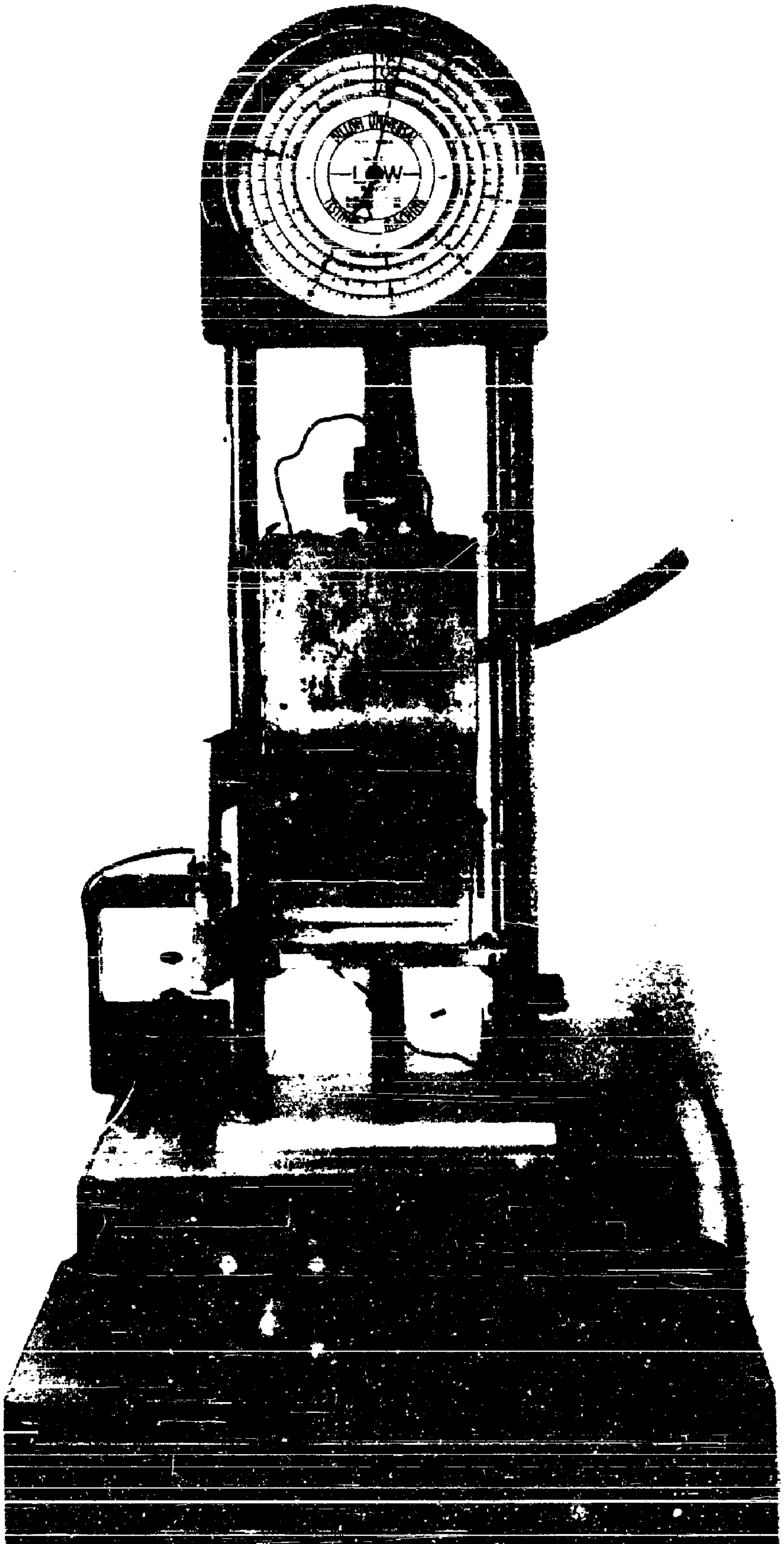


Figure No. 72 - Front View of the Elevated Temperature Peel Test Chamber

shown in Figure No. 72 are two teflon spacers which go between the test specimen and the specimen fixture. A high strength wire was fastened to the jaws of the clamping device (clamping device is shown in Figure No. 72). The wire has a spring clamp at the other end which clamped to the ~~to the~~ copper foil. A thermostat probe was inserted near the test specimen. The heat was supplied by a 600 watt resistance coil heater which is fastened inside the chamber. Calibration was performed to find the right dial setting on the rheostat to correspond to the temperature reading desired.

For measuring the temperature in the test chamber a Fenwal Bead No. GB34P9 and teflon wire plus a temperature meter indicating temperature directly was used to monitor the test peel temperature. (See Figure No. 72.) For the dimensions and overall detailed design of the test chamber, see Figure No. 73. It should be noted that the test chamber is portable and was bolted to the test plate on the peel tester (see Figure No. ~~71~~).
72

See Figure NO. 74 for the electrical circuit hook-up.

5.4 Test Procedure

The elevated peel test chamber was heated to the desired test temperature and allowed to reach equilibrium before the specimen was put in the chamber. The test specimen copper strip was peeled back enough to allow the clamp in the test chamber to take hold of the peel strip. The specimen was then placed in the specimen device and the two Allen head screws were tightened down on the teflon spacers between screw and test specimen. The chamber door was closed and the specimen allowed to soak for one hour before performing the peel test. All tests were performed at the elevated temperature in the oven. (Test temperature was held at $\pm$ 2^{o} F.) For comparison, some of the test specimens were soaked in an air circulating oven for 1 hour before peel testing. It took 30 seconds to transfer the specimen from oven to test chamber, and very little difference was found in the peel test values.

5.5 Analysis of Elevated Peel Test Results

Tables 51 through 69 show the peel test results. A summary of both 1 and 2 oz. peel test results for all the materials are in Tables 70 and 71. Referring to these two summary tables, it can be seen that the peel strength for all of the test speciments was reduced by approximately 50%, comparing with those as specified for MIL-P-13949B. The peel strength data for the 1/32" material was lower than the 1/8" because at elevated temperatures the 1/32" material will give more than the 1/8" material because of a smaller cross sectional area.

5.6 Conclusions

The follwoing conclusions are based on test data reported:

1. The peel test elevated test chamber design was satisfactory to fulfill test requirements set forth in MIL-P-13949B.

   This chamber design did not have a circulating air system, consequently elevated peel tests were performed without circulating air and test speciments were pre-conditioned for one hour in a circulating air oven. Very little difference was observed when two like test speciments were tested at the same temperature, but conditioned differently.

2. There was slight discoloration of all laminate base types when pulled at the specified test temperature.

3. The elevated peel test results of all copper clad laminate speciments (1 and 2 oz. copper) showed approximately 50 to 70% reduction in peel strength value.

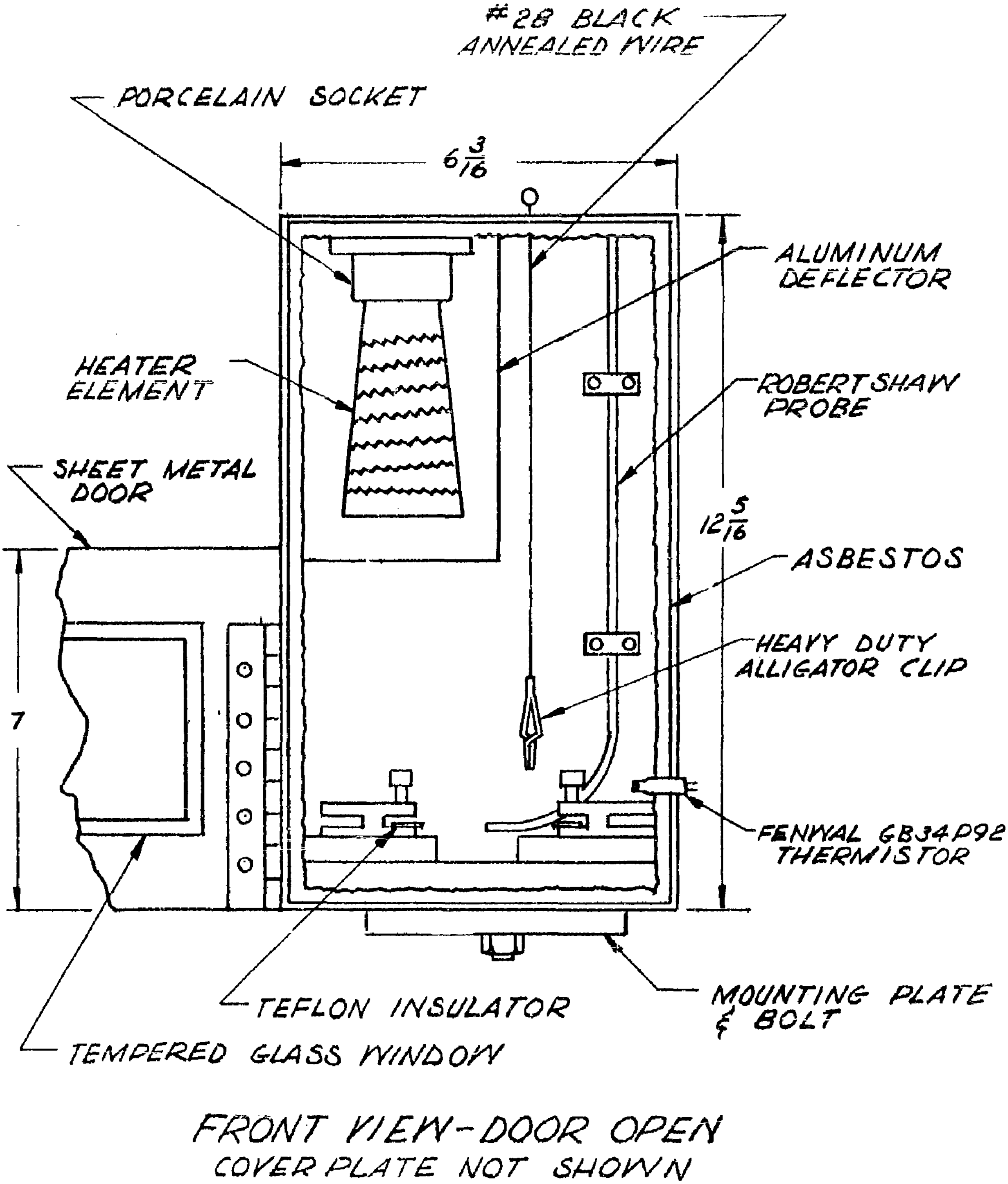
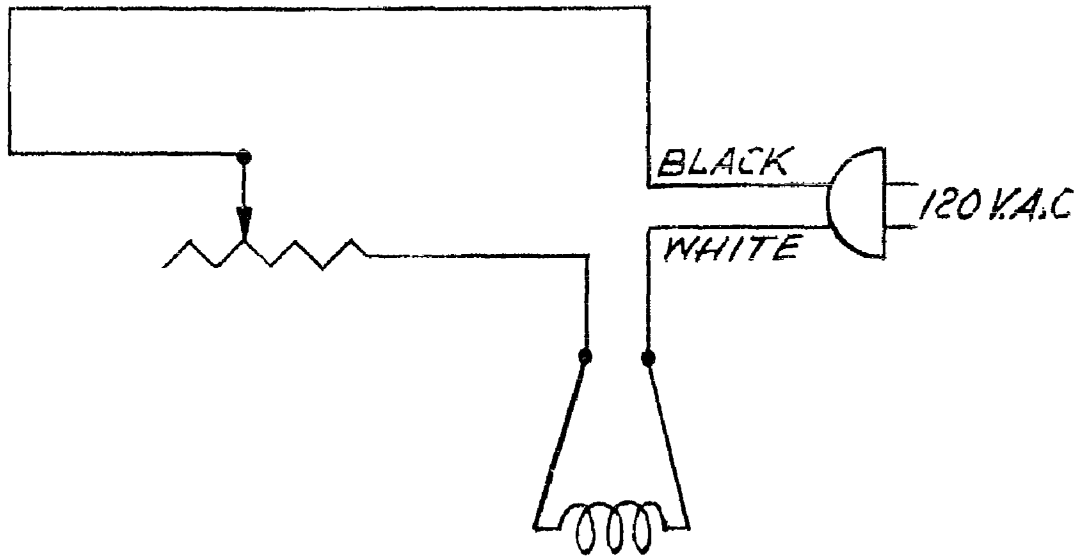


Figure No. 73. Elevated Temperature Test Chamber



CONDUCTORS #12 AWG
HEATER 2.0 OHMS
POTENTIOMETER 2.5 OHMS
OPERATING CURRENT 44.0 AMPERES
OPERATING VOLTAGE 120-130 V.A.C.

Figure No. 74. Electrical Circuit For Test Chamber

TABLE LI

PEEL STRENGTH TEST RESULTS OF PAPER PHENOLIC OF MANUFACTURER A (TESTED AT 248° F.)

Spec. No.	Laminate Thickness (Inch)	Copper Foil Wt. (Oz.)	Base Laminate	Manufacturer	Test Temp. °F	Peel Strength (Lbs/Inch)	Peel Test Value Per MIL-P-13949B
1	1/32	1	Paper Phenolic (PP)	A	248	1.75	6
2	1/32	1	Paper Phenolic (PP)	A	248	2.10	6
3	1/32	1	Paper Phenolic (PP)	A	248	1.85	6
4	1/32	1	Paper Phenolic (PP)	A	248	1.95	6
Average Peel Test Value						1.91	6
5	1/32	2	Paper Phenolic (PP)	A	248	1.10	7
6	1/32	2	Paper Phenolic (PP)	A	248	1.95	7
7	1/32	2	Paper Phenolic (PP)	A	248	2.00	7
8	1/32	2	Paper Phenolic (PP)	A	248	1.10	7
Average Peel Test Value						1.54	7
9	1/8	1	Paper Phenolic (PP)	A	248	3.00	6
10	1/8	1	Paper Phenolic (PP)	A	248	3.40	6
11	1/8	1	Paper Phenolic (PP)	A	248	3.70	6

TABLE LI (CONT)

PEEL STRENGTH TEST RESULTS OF PAPER PHENOLIC OF MANUFACTURER A (TESTED AT 248° F.)

Spec. No.	Laminate Thickness (Inch)	Copper Foil Wt. (Oz.)	Base Laminate	Manufacturer	Test Temp. °F	Peel Strength (Lbs/Inch)	Peel Test Value Per MIL-P-13949 B
12	1/8	1	Paper Phenolic (PP)	A	248	3.10	6
Average Peel Test Value						3.30	6
13	1/8	2	Paper Phenolic (PP)	A	248	3.76	7
14	1/8	2	Paper Phenolic (PP)	A	248	4.04	7
15	1/8	2	Paper Phenolic (PP)	A	248	4.15	7
16	1/8	2	Paper Phenolic (PP)	A	248	3.94	7
Average Peel Test Value						3.75	7

TABLE LII

PEEL STRENGTH TEST RESULTS OF PAPER PHENOLIC OF MANUFACTURER B
(TESTED AT 248° F.)

Spec. No.	Laminate Thickness (Inch)	Copper Foil Wt. (Oz.)	Base Laminate	Manufacturer	Test Temp. °F	Peel Strength (Lbs/Inch)	Peel Test Value Per MIL-P-13949 B
17	1/32	1	Paper Phenolic (PP)	B	248	1.62	6
18	1/32	1	Paper Phenolic (PP)	B	248	1.00	6
19	1/32	1	Paper Phenolic (PP)	B	248	1.00	6
20	1/32	1	Paper Phenolic (PP)	B	248	1.20	6
Average Peel Test Value						1.21	6
21	1/32	2	Paper Phenolic (PP)	B	248	3.00	7
22	1/32	2	Paper Phenolic (PP)	B	248	3.40	7
23	1/32	2	Paper Phenolic (PP)	B	248	3.20	7
24	1/32	2	Paper Phenolic (PP)	B	248	3.90	7
Average Peel Test Value						3.38	7
25	1/8	1	Paper Phenolic (PP)	B	248	3.62	6
26	1/8	1	Paper Phenolic (PP)	B	248	2.48	6

TABLE LII (CONT)

PEEL STRENGTH TEST RESULTS OF PAPER PHENOLIC OF MANUFACTURER B (TESTED AT 248° F.)

Spec. No.	Laminate Thickness (Inch)	Copper Foil Wt. (Oz.)	Base Laminate	Manufacturer	Test Temp. °F	Peel Strength (Lbs/Inch)	Peel Test Value Per MIL-P-13949B
27	1/8	1	Paper Phenolic (PP)	B	248	3.81	6
28	1/8	1	Paper Phenolic (PP)	B	248	3.70	6
Average Peel Test Value						3.41	6
29	1/8	2	Paper Phenolic (PP)	B	248	5.00	7
30	1/8	2	Paper Phenolic (PP)	B	248	5.00	7
31	1/8	2	Paper Phenolic (PP)	B	248	5.10	7
32	1/8	2	Paper Phenolic (PP)	B	248	4.80	7
Average Peel Test Value						4.98	7

TABLE LIII

PEEL STRENGTH TEST RESULTS OF PAPER PHENOLIC OF MANUFACTURER C
(TESTED AT 248° F.)

Spec. No.	Laminate Thickness (Inch)	Copper Foil Wt. (Oz.)	Base Laminate	Manufacturer	Test Temp. °F	Peel Strength (Lbs/Inch)	Peel Test Value Per MIL-P-13949B
33	1/32	1	Paper Phenolic (PP)	C	248	2.00	6
34	1/32	1	Paper Phenolic (PP)	C	248	2.00	6
35	1/32	1	Paper Phenolic (PP)	C	248	2.00	6
36	1/32	1	Paper Phenolic (PP)	C	248	2.58	6
Average Peel Test Value						2.14	6
37	1/32	2	Paper Phenolic (PP)	C	248	6.00	7
38	1/32	2	Paper Phenolic (PP)	C	248	6.50	7
39	1/32	2	Paper Phenolic (PP)	C	248	4.95	7
40	1/32	2	Paper Phenolic (PP)	C	248	4.89	7
Average Peel Test Value						5.58	7
41	1/8	1	Paper Phenolic (PP)	C	248	2.99	6
42	1/8	1	Paper Phenolic (PP)	C	248	2.00	6

TABLE LIII (CONT)

PEEL STRENGTH TEST RESULTS OF PAPER PHENOLIC OF MANUFACTURER C
(TESTED AT 248° F.)

Spec. No.	Laminate Thickness (Inch)	Copper Foil Wt. (Oz.)	Base Laminate	Manufacturer	Test Temp. °F	Peel Strength (Lbs/Inch)	Peel Test Value Per MIL-P-13949B
43	1/8	1	Paper Phenolic (PP)	C	248	3.00	6
44	1/8	1	Paper Phenolic (PP)	C	248	2.71	6
Average Peel Test Value						2.68	6
45	1/8	2	Paper Phenolic (PP)	C	248	5.95	7
46	1/8	2	Paper Phenolic (PP)	C	248	6.40	7
47	1/8	2	Paper Phenolic (PP)	C	248	5.55	7
48	1/8	2	Paper Phenolic (PP)	C	248	5.00	7
Average Peel Test Value						5.73	7

TABLE LIV

PEEL STRENGTH TEST RESULTS OF PAPER EPOXY OF MANUFACTURER A
(TESTED AT 248° F.)

Spec. No.	Laminate Thickness (Inch)	Copper Foil Wt. (Oz.)	Base Laminate	Manufacturer	Test Temp. °F	Peel Strength (Lbs/Inch)	[1] Peel Test Value Per MIL-P-13949B
49	1/32	1	Paper Epoxy (PX)	A	248	2.78	9
50	1/32	1	Paper Epoxy (PX)	A	248	2.00	9
51	1/32	1	Paper Epoxy (PX)	A	248	2.49	9
52	1/32	1	Paper Epoxy (PX)	A	248	2.90	9
AveragePeel Test Value						2.54	9
53	1/32	2	Paper Epoxy (PX)	A	248	3.00	13
54	1/32	2	Paper Epoxy (PX)	A	248	3.00	13
55	1/32	2	Paper Epoxy (PX)	A	248	3.49	13
56	1/32	2	Paper Epoxy (PX)	A	248	3.52	13
Average Peel Test Value						3.25	13
57	1/8	1	Paper Epoxy (PX)	A	248	4.00	9
58	1/8	1	Paper Epoxy (PX)	A	248	4.00	9
59	1/8	1	Paper Epoxy (PX)	A	248	4.00	9

1 Refer to Task E on Peel Strength Values in the Summary Table on Physical Properties of Paper Epoxy

TABLE LIV (CONT)

PEEL STRENGTH TEST RESULTS OF PAPER EPOXY OF MANUFACTURER A
(TESTED AT 248° F.)

Spec. No.	Laminate Thickness (Inch)	Copper Foil Wt. (Oz.)	Base Laminate	Manufacturer	Test Temp. °F	Peel Strength (Lbs/Inch)	[1] Peel Test Value Per MIL-P-13949B
60	1/8	1	Paper Epoxy (PX)	A	248	4.99	9
Average Peel Test Value						4.24	9
61	1/8	2	Paper Epoxy (PX)	A	248	5.60	13
62	1/8	2	Paper Epoxy (PX)	A	248	5.20	13
63	1/8	2	Paper Epoxy (PX)	A	248	5.25	13
64	1/8	2	Paper Epoxy (PX)	A	248	5.45	13
Average Peel Test Value						5.38	13

1 Refer to Task E on Peel Strength Values in the Summary Table on Physical Properties of Paper Epoxy

TABLE LV

PEEL STRENGTH TEST RESULTS OF PAPER EPOXY OF MANUFACTURER B (TESTED AT 248° F.)

Spec. No.	Laminate Thickness (Inch)	Copper Foil Wt. (Oz.)	Base Laminate	Manufacturer	Test Temp. °F	Peel Strength (Lbs/Inch)	[1] Peel Test Value Per MIL-P-13949B
65	1/32	1	Paper Epoxy (PX)	B	248	2.00	9
66	1/32	1	Paper Epoxy (PX)	B	248	2.49	9
67	1/32	1	Paper Epoxy (PX)	B	248	3.50	9
68	1/32	1	Paper Epoxy (PX)	B	248	3.10	9
Average Peel Test Value						2.77	9
69	1/32	2	Paper Epoxy (PX)	B	248	5.52	13
70	1/32	2	Paper Epoxy (PX)	B	248	5.50	13
71	1/32	2	Paper Epoxy (PX)	B	248	6.00	13
72	1/32	2	Paper Epoxy (PX)	B	248	6.10	13
Average Peel Test Value						5.77	13
73	1/8	1	Paper Epoxy (PX)	B	248	4.00	9
74	1/8	1	Paper Epoxy (PX)	B	248	5.50	9
75	1/8	1	Paper Epoxy (PX)	B	248	5.00	9

1 Refer to Task E on Peel Strength Values in the Summary Table on Physical Properties of Paper Epoxy

TABLE LV (CONT)

PEEL STRENGTH TEST RESULTS OF PAPER EPOXY OF MANUFACTURER B (TESTED AT 248° F.)

Spec. No.	Laminate Thickness (Inch)	Copper Foil Wt. (Oz.)	Base Laminate	Manufacturer	Test Temp. °F	Peel Strength (Lbs/Inch)	[1] Peel Test Value Per MIL-P-13949 B
76	1/8	1	Paper Epoxy (PX)	B	248	5.00	9
Average Peel Test Value						4.88	9
77	1/8	2	Paper Epoxy (PX)	B	248	6.00	13
78	1/8	2	Paper Epoxy (PX)	B	248	5.95	13
79	1/8	2	Paper Epoxy (PX)	B	248	5.84	13
80	1/8	2	Paper Epoxy (PX)	B	248	5.90	13
Average Peel Test Value						5.93	13

1 Refer to Task E on Peel Strength Values in the Summary Table on Physical Properties of Paper Epoxy

TABLE LVI

PEEL STRENGTH TEST RESULTS OF PAPER EPOXY OF MANUFACTURER D (TESTED AT 248° F.)

Spec. No.	Laminate Thickness Inch)	Copper Foil Wt. (Oz.)	Base Laminate	Manufacturer	Test Temp. °F	Peel Strength (Lbs/inch)	[1] Peel Test Value Per MIL-P-13949B
81	1/32	1	Paper Epoxy (PX)	D	248	3.00	9
82	1/32	1	Paper Epoxy (PX)	D	248	2.70	9
83	1/32	1	Paper Epoxy (PX)	D	248	2.00	9
84	1/32	1	Paper Epoxy (PX)	D	248	2.99	9
Average Peel Test Value						2.67	9
85	1/32	2	Paper Epoxy (PX)	D	248	3.70	13
86	1/32	2	Paper Epoxy (PX)	D	248	3.84	13
87	1/32	2	Paper Epoxy (PX)	D	248	3.98	13
88	1/32	2	Paper Epoxy (PX)	D	248	3.75	13
Average Peel Test Value						3.81	13
89	1/8	1	Paper Epoxy (PX)	D	248	3.70	9
90	1/8	1	Paper Epoxy (PX)	D	248	3.51	9

1 Refer to Task E on Peel Strength Values in the Summary Table on Physical Properties of Paper Epoxy

TABLE LVI (CONT)

PEEL STRENGTH TEST RESULTS OF PAPER EPOXY OF MANUFACTURER D (TESTED AT 248° F.)

Spec. No.	Laminate Thickness (Inch)	Copper Foil Wt. (Oz.)	Base Laminate	Manufacturer	Test Temp. °F	Peel Strength (Lbs/Inch)	Peel Test Value Per MIL-P-13949B
91	1/8	1	Paper Epoxy (PX)	D	248	3.00	9
92	1/8	1	Paper Epoxy (PX)	D	248	3.51	9
Average Peel Test Value						3.44	9
93	1/8	2	Paper Epoxy (PX)	D	248	6.25	13
94	1/8	2	Paper Epoxy (PX)	D	248	6.14	13
95	1/8	2	Paper Epoxy (PX)	D	248	5.84	13
96	1/8	2	Paper Epoxy (PX)	D	248	5.90	13
Average Peel Test Value						6.03	13

1 Refer to Task E on Peel Strength Values in the Summary Table on Physical Properties of Paper Epoxy

TABLE LVII

PEEL STRENGTH TEST RESULTS OF GLASS EPOXY OF MANUFACTURER A-GE (TESTED AT 284° F.)

Spec. No.	Laminate Thickness (Inch)	Copper Foil Wt. (Oz.)	Base Laminate	Manufacturer	Test Temp. °F	Peel Strength (Lbs/Inch)	Peel Test Value Per MIL-P-13949B
97	1/32	1	Glass Epoxy (GE)	A	284	3.84	7
98	1/32	1	Glass Epoxy (GE)	A	284	3.48	7
99	1/32	1	Glass Epoxy (GE)	A	284	3.64	7
100	1/32	1	Glass Epoxy (GE)	A	284	3.60	7
Average Peel Test Value						3.64	7
101	1/32	2	Glass Epoxy (GE)	A	284	4.02	9
102	1/32	2	Glass Epoxy (GE)	A	284	4.14	9
103	1/32	2	Glass Epoxy (GE)	A	284	4.18	9
104	1/32	2	Glass Epoxy (GE)	A	284	4.25	9
Average Peel Test Value						4.14	9
105	1/8	1	Glass Epoxy (GE)	A	284	7.50	7
106	1/8	1	Glass Epoxy (GE)	A	284	6.00	7
107	1/8	1	Glass Epoxy (GE)	A	284	6.40	7

TABLE LVII (CONT)

PEEL STRENGTH TEST RESULTS OF GLASS EPOXY OF MANUFACTURER A-GE (TESTED AT 284° F.)

Spec. No.	Laminate Thickness (Inch)	Copper Foil Wt. (Oz.)	Base Laminate	Manufacturer	Test Temp. °F	Peel Strength (Lbs/Inch)	Peel Test Value Per MIL-P-13949B
108	1/8	1	Glass Epoxy (GE)	A	284	6.70	7
Average Peel Test Value						6.65	7
109	1/8	2	Glass Epoxy (GE)	A	284	5.60	9
110	1/8	2	Glass Epoxy (GE)	A	284	5.20	9
111	1/8	2	Glass Epoxy (GE)	A	284	5.45	9
112	1/8	2	Glass Epoxy (GE)	A	284	5.00	9
Average Peel Test Value						5.30	9

TABLE LVIII

PEEL STRENGTH TEST RESULTS OF GLASS EPOXY OF MANUFACTURER B-GE
(TESTED AT 284° F.)

Spec. No.	Laminate Thickness (Inch)	Copper Foil Wt. (Oz.)	Base Laminate	Manufacturer	Test Temp. °F	Peel Strength (Lbs/Inch)	Peel Test Value Per MIL-P-13949B
113	1/8	1	Glass Epoxy (GE)	B	284	2.00	7
114	1/8	1	Glass Epoxy (GE)	B	284	2.49	7
115	1/8	1	Glass Epoxy (GE)	B	284	2.00	7
116	1/8	1	Glass Epoxy (GE)	B	284	2.00	7
Average Peel Test Value						2.12	7
117	1/8	2	Glass Epoxy (GE)	B	284	4.25	9
118	1/8	2	Glass Epoxy (GE)	B	284	4.18	9
119	1/8	2	Glass Epoxy (GE)	B	284	4.04	9
120	1/8	2	Glass Epoxy (GE)	B	284	4.40	9
Average Peel Test Value						4.22	9

TABLE LIX

PEEL STRENGTH TEST RESULTS OF GLASS EPOXY OF MANUFACTURER C-GE
(TESTED AT 284° F.)

Spec. No.	Laminate Thickness (Inch)	Copper Foil Wt. (Oz.)	Base Laminate	Manufacturer	Test Temp. °F	Peel Strength (Lbs/Inch)	Peel Test Value Per MIL-P-13949B
121	1/8	1	Glass Epoxy (GE)	C	284	3.51	7
122	1/8	1	Glass Epoxy (GE)	C	284	2.49	7
123	1/8	1	Glass Epoxy (GE)	C	284	2.50	7
124	1/8	1	Glass Epoxy (GE)	C	284	2.49	7
Average Peel Test Value						2.74	7
125	1/8	2	Glass Epoxy (GE)	C	284	3.51	9
126	1/8	2	Glass Epoxy (GE)	C	284	4.05	9
127	1/8	2	Glass Epoxy (GE)	C	284	3.10	9
128	1/8	2	Glass Epoxy (GE)	C	284	3.50	9
Average Peel Test Value						3.54	9

TABLE LX

PEEL STRENGTH TEST RESULTS OF TEMPERATURE RESISTANT GLASS EPOXY OF MANUFACTURER A-GB (TESTED AT 284° F.)

Spec. No.	Laminate Thickness (Inch)	Copper Foil Wt. (Oz.)	Base Laminate	Manufacturer	Test Temp. °F	Peel Strength (Lbs/Inch)	Peel Test Value Per MIL-P-13949B
129	1/8	1	Epoxy Glass (GB)	A	284	3.51	7
130	1/8	1	Epoxy Glass (GB)	A	284	4.00	7
131	1/8	1	Epoxy Glass (GB)	A	284	3.00	7
132	1/8	1	Epoxy Glass (GB)	A	284	3.00	7
Average Peel Test Value						3.38	7
133	1/8	2	Epoxy Glass (GB)	A	284	3.84	9
134	1/8	2	Epoxy Glass (GB)	A	284	4.03	9
135	1/8	2	Epoxy Glass (GB)	A	284	3.25	9
136	1/8	2	Epoxy Glass (GB)	A	284	3.74	9
Average Peel Test Value						3.71	9

TABLE LXI

PEEL STRENGTH TEST RESULTS OF TEMPERATURE RESISTANT GLASS EPOXY OF MANUFACTURER B-GB (TESTED AT 284° F.)

Spec. No.	Laminate Thickness (Inch)	Copper Foil Wt. (Oz.)	Base Laminate	Manufacturer	Test Temp. °F	Peel Strength (Lbs/Inch)	Peel Test Value Per MIL-P-13949B
137	1/8	1	Epoxy Glass (GB)	B	284	1.05	7
138	1/8	1	Epoxy Glass (GB)	B	284	1.15	7
139	1/8	1	Epoxy Glass (GB)	B	284	2.00	7
140	1/8	1	Epoxy Glass (GB)	B	284	2.00	7
Average Peel Test Value						1.55	7
141	1/8	2	Epoxy Glass (GB)	B	284	2.45	9
142	1/8	2	Epoxy Glass (GB)	B	284	2.75	9
143	1/8	2	Epoxy Glass (GB)	B	284	3.00	9
144	1/8	2	Epoxy Glass (GB)	B	284	2.94	9
Average Peel Test Value						2.85	9

TABLE LXII

PEEL STRENGTH TEST RESULTS OF TEMPERATURE RESISTANT GLASS EPOXY OF MANUFACTURER C-GB (TESTED AT 284° F.)

Spec. No.	Laminate Thickmess (Inch)	Copper Foil Wt. (Oz.)	Base Laminate	Manufacturer	Test Temp. °F	Peel Strength (Lbs/Inch)	Peel Test Value Per MIL-P-13949B
145	1/8	1	Epoxy Glass (GB)	C	284	2.34	7
146	1/8	1	Epoxy Glass (GB)	C	284	2.49	7
147	1/8	1	Epoxy Glass (GB)	C	284	2.61	7
148	1/8	1	Epoxy Glass (GB)	C	284	2.84	7
Average Peel Test Value						2.57	7
149	1/8	2	Epoxy Glass (GB)	C	284	3.74	9
150	1/8	2	Epoxy Glass (GB)	C	284	3.46	9
151	1/8	2	Epoxy Glass (GB)	C	284	3.59	9
152	1/8	2	Epoxy Glass (GB)	C	284	3.64	9
Average Peel Test Value						3.61	9

TABLE LXIII

PEEL STRENGTH TEST RESULTS OF FLAME RETARDANT GLASS EPOXY OF MANUFACTURER A-GF (TESTED AT 284° F.)

Spec. No.	Laminate Thickness (Inch)	Copper Foil Wt. (Oz.)	Base Laminate	Manufacturer	Test Temp. °F	Peel Strength (Lbs/Inch)	Peel Test Value Per MIL-P-13949B
153	1/8	1	Epoxy Glass (GF)	A	284	2.08	7
154	1/8	1	Epoxy Glass (GF)	A	284	2.01	7
155	1/8	1	Epoxy Glass (GF)	A	284	1.60	7
156	1/8	1	Epoxy Glass (GF)	A	284	1.90	7
Average Peel Test Value						1.89	7
157	1/8	2	Epoxy Glass (GF)	A	284	2.90	9
158	1/8	2	Epoxy Glass (GF)	A	284	3.00	9
159	1/8	2	Epoxy Glass (GF)	A	284	2.56	9
160	1/8	2	Epoxy Glass (GF)	A	284	3.00	9
Average Peel Test Value						2.86	9

TABLE LXIV

PEEL STRENGTH TEST RESULTS OF FLAME RETARDANT GLASS EPOXY OF MANUFACTURER B-GF (TESTED AT 284° F.)

Spec. No.	Laminate Thickness (Inch)	Copper Foil Wt. (Oz.)	Base Laminate	Manufacturer	Test Temp. °F	Peel Strength (Lbs/Inch)	Peel Test Value Per MIL-P-13949B
161	1/8	1	Glass Epoxy (GF)	B	284	2.00	7
162	1/8	1	Glass Epoxy (GF)	B	284	2.00	7
163	1/8	1	Glass Epoxy (GF)	B	284	1.52	7
164	1/8	1	Glass Epoxy (GF)	B	284	2.00	7
Average Peel Test Value						1.88	7
165	1/8	2	Glass Epoxy (GF)	B	284	2.00	9
166	1/8	2	Glass Epoxy (GF)	B	284	2.00	9
167	1/8	2	Glass Epoxy (GF)	B	284	2.00	9
168	1/8	2	Glass Epoxy (GF)	B	284	2.00	9
Average Pe ' Test Value						2.00	9

TABLE LXV

PEEL STRENGTH TEST RESULTS OF FLAME RETARDANT GLASS EPOXY OF MANUFACTURER C-GF (TESTED AT 284° F.)

Spec. No.	Laminate Thickness (Inch)	Copper Foil Wt. (Oz.)	Base Laminate	Manufacturer	Test Temp. °F	Peel Strength (Lbs/Inch)	Peel Test Value Per MIL-P-13949B
169	1/8	1	Glass Epoxy (GF)	C	284	5.00	7
170	1/8	1	Glass Epoxy (GF)	C	284	4.00	7
171	1, 8	1	Glass Epoxy (GF)	C	284	5.00	7
172	1/8	1	Glass Epoxy (GF)	C	284	5.00	7
Average Peel Test Value						4.75	7
173	1/8	2	Glass Epoxy (GE)	C	284	5.28	9
174	1/8	2	Glass Epoxy (GF)	C	284	5.38	9
175	1/8	2	Glass Epoxy (GF)	C	284	5.00	9
176	1/8	2	Glass Epoxy (GF)	C	284	4.85	9
Average Peel Test Value						5/1.3	9

TABLE LXVI

PEEL STRENGTH TEST RESULTS OF GLASS MELAMINE OF MANUFACTURER A (TESTED AT 284° F.)

Spec. No.	Laminate Thickness (Inch)	Copper Foil Wt. (Oz.)	Base Laminate	Manufacturer	Test Temp. °F	Peel Strength (Lbs/Inch)	Peel Test Value Per MIL-P-13949B
177	1/8	1	Glass Melamine (GM)	A	284	4.00	9
178	1/8	1	Glass Melamine (GM)	A	284	4.00	9
179	1/8	1	Glass Melamine (GM)	A	284	3.83	9
180	1/8	1	Glass Melamine (GM)	A	284	3.85	9
Average Peel Test Value						3.92	9
181	1/8	2	Glass Melamine (GM)	A	284	3.00	9
182	1/8	2	Glass Melamine (GM)	A	284	4.00	9
183	1/8	2	Glass Melamine (GM)	A	284	3.00	9
184	1/8	2	Glass Melamine (GM)	A	284	3.50	9
Average Peel Test Value						3.38	9

TABLE LXVII

PEEL STRENGTH TEST RESULTS OF GLASS SILICONE OF MANUFACTURER A (TESTED AT 284° F.)

Spec. No.	Laminate Thickness (Inch)	Copper Foil Wt. (Oz.)	Base Laminate	Manufacturer	Test Temp. °F	Peel Strength (Lbs/Inch)	Peel Test Value Per MIL-P-13949B
185	1/8	1	Glass Silicone (GS)	A	284	2.72	5
186	1/8	1	Glass Silicone (GS)	A	284	4.00	5
187	1/8	1	Glass Silicone (GS)	A	284	3.85	5
188	1/8	1	Glass Silicone (GS)	A	284	3.00	5
Average Peel Test Value						3.39	5
189	1/8	2	Glass Silicone (GS)	A	284	5.50	5
190	1/8	2	Glass Silicone (GS)	A	284	5.34	5
191	1/8	2	Glass Silicone (GS)	A	284	5.00	5
192	1/8	2	Glass Silicone (GS)	A	284	5.00	5
Average Peel Test Value						5.21	5

TABLE LXVIII

PEEL STRENGTH TEST RESULTS OF GLASS TEFLON OF MANUFACTURER B
(TESTED AT 393 ° F.)

Spec. No.	Laminate Thickness (Inch)	Copper Foil Wt. (Oz.)	Base Laminate	Manufacturer	Test Temp. °F	Peel Strength (Lbs/Inch)	1 Peel Test Value Per MIL-P-13949B
193	1/8	1	Glass Teflon (GT)	B	393	2.49	5
194	1/8	1	Glass Teflon (GT)	B	393	2.30	5
195	1/8	1	Glass Teflon (GT)	B	393	1.99	5
196	1/8	1	Glass Teflon (GT)	B	393	2.44	5
Average Peel Test Value						2.31	5
197	1/8	2	Glass Teflon (GT)	B	393	3.50	6
198	1/8	2	Glass Teflon (GT)	B	393	3.90	6
199	1/8	2	Glass Teflon (GT)	B	393	3.46	6
200	1/8	2	Glass Teflon (GT)	B	393	3.50	6
Average Peel Test Value						3.59	6

1 See Proposed MIL-P-13949C Specifications

TABLE LXIX

PEEL STRENGTH TEST RESULTS OF GLASS TEFLON OF MANUFACTURER E
(TESTED AT 393° F.)

Spec. No.	Laminate Thickness (inch)	Copper Foil Wt. (Oz.)	Base Laminate	Manufacturer	Test Temp. °F	Peel Strength (Lbs/Inch)	[1] Peel Test Value Per MIL-P-13949B
201	1/8	1	Glass Teflon (GT)	E	393	1.00	5
202	1/8	1	Glass Teflon (GT)	E	393	0.49	5
203	1/8	1	Glass Teflon (GT)	E	393	1.00	5
204	1/8	1	Glass Teflon (GT)	E	393	1.57	5
Average Peel Test Value						1.01	5
205	1/8	2	Glass Teflon (GT)	E	393	2.00	6
206	1/8	2	Glass Teflon (GT)	E	393	1.60	6
207	1/8	2	Glass Teflon (GT)	E	393	1.50	6
208	1/8	2	Glass Teflon (GT)	E	393	1.50	6
Average Peel Test Value						1.65	6

1 See Proposed MIL-P-13949C Specification

TABLE LXX

SUMMARY OF PEEL STRENGTH TEST RESULTS PERFORMED AT ELEVATED TEMPERATURES ON 1 OZ. SPECIMINES.

Base Laminate	Manu-facturer	Laminate Thickness (Inch)	Copper Foil Wt. (Oz.)	Test Temp. °F	Averaged Peel Strength Value (Lbs./In.-Width	Peel Test Value Per MIL-P-13949B
Paper Phenolic (PP)	A	1/32	1	248	1.91	6
Paper Phenolic (PP)	A	1/8	1	248	3.30	6
Paper Phenolic (PP)	B	1/32	1	248	1.21	6
Paper Phenolic (PP)	B	1/8	1	248	3.41	6
Paper Phenolic (PP)	C	1/32	1	248	2.14	6
Paper Phenolic (PP)	C	1/8	1	248	2.68	6
Paper Epoxy (PX)*	A	1/32	1	248	2.54	9
Paper Epoxy (PX)*	A	1/8	1	248	4.24	9
Paper Epoxy (PX)*	B	1/32	1	248	2.77	9
Paper Epoxy (PX)*	B	1/8	1	248	4.88	9
Paper Epoxy (PX)*	D	1/32	1	248	2.67	9
Paper Epoxy (PX)*	D	1/8	1	248	3.44	9
Glass Epoxy (GE)	A	1/32	1	284	3.64	7
Glass Epoxy (GE)	A	1/8	1	284	6.65	7
Glass Epoxy (GE)	B	1/8	1	284	2.12	7
Glass Epoxy (GE)	C	1/8	1	284	2.74	7
Glass Epoxy (GB)	A	1/8	1	284	3.38	7
Glass Epoxy (GB)	B	1/8	1	284	1.55	7
Glass Epoxy (GB)	C	1/8	1	284	2.57	7
Glass Epoxy (GF)	A	1/8	1	284	1.89	7
Glass Epoxy (GF)	B	1/8	1	284	1.88	7
Glass Epoxy (GF)	C	1/8	1	284	4.75	7
Glass Melamine (GM)	A	1/8	1	284	3.92	9
Glass Silicone (GS)	A	1/8	1	284	3.39	5
Glass Teflon (GT)	B	1/8	1	393	2.31	5
Glass Teflon (GT)	E	1/8	1	393	1.01	5

* Refer to Task E on Peel Strength Minimum Values in the Summary Table on Physical Properties of Paper Epoxy

TABLE LXXI

SUMMARY OF PEEL STRENGTH TEST RESULTS PERFORMED AT ELEVATED TEMPERATURES ON 2 OZ. SPECIMINES.

Base Laminate	Manufacturer	Laminate Thickness (Inch)	Copper Foil Wt. (Oz.)	Test Temp. °F	Averaged Peel Strength Value (Lbs./In.-Width)	Peel Test Value Per MIL-P-13949B
Paper Phenolic (PP)	A	1/32	2	248	1.54	7
Paper Phenolic (PP)	A	1/8	2	248	3.75	7
Paper Phenolic (PP)	B	1/32	2	248	3.38	7
Paper Phenolic (PP)	B	1/8	2	248	4.98	7
Paper Phenolic (PP)	C	1/32	2	248	5.58	7
Paper Phenolic (PP)	C	1/8	2	248	5.73	7
Paper Epoxy (PX) *	A	1/32	2	248	3.25	13
Paper Epoxy (PX) *	A	1/8	2	248	5.38	13
Paper Epoxy (PX) *	B	1/32	2	248	5.77	13
Paper Epoxy (PX) *	B	1/8	2	248	5.93	13
Paper Epoxy (PX) *	D	1/32	2	248	3.81	13
Paper Epoxy (PX) *	D	1/8	2	248	6.03	13
Glass Epoxy (GE)	A	1/32	2	284	4.14	9
Glass Epoxy (GE)	A	1/8	2	284	5.30	9
Glass Epoxy (GE)	B	1/8	2	284	4.22	9
Glass Epoxy (GE)	C	1/8	2	284	3.54	9
Glass Epoxy (GB)	A	1/8	2	284	3.71	9
Glass Epoxy (GB)	B	1/8	2	284	2.85	9
Glass Epoxy (GB)	C	1/8	2	284	3.61	9
Glass Epoxy (GF)	A	1/8	2	284	2.86	9
Glass Epoxy (GF)	B	1/8	2	284	2.00	9
Glass Epoxy (GF)	C	1/8	2	284	5.13	9
Glass Melamine (GM)	A	1/8	2	284	3.38	9
Glass Silicone (GS)	A	1/8	2	284	5.21	5
Glass Teflon (GT)	B	1/8	2	393	3.59	6
Glass Teflon (GT)	E	1/8	2	393	1.65	6

* Refer to Task E on Peel Strength Minimum Values in the Summary Table on Physical Properties of Paper Epoxy

6. Task E - The Physical, Mechanical and Electrical Property Evaluation of Paper Epoxy

6.1 Purpose - This report has been prepared to present the final results and conclusions on the physical, mechanical and electrical properties of copper clad paper base epoxy laminate, evaluated in accordance with the requirements of MIL-P-13949B. The information has been analyzed and a tentative data sheet prepared for inclusion in this specification.

6.2 General Data

6.2.1 Background - Existing military specifications have not provided for the use of foil clad paper base epoxy materials. In many cases, these materials have properties which make their use more desirable than other approved materials, particularly where a high degree of machineability is required at a relatively modest cost.

6.2.2 Scope - The tests performed were all conducted in accordance with the requirements of MIL-P-13949B and were carried out on copper clad paper base epoxy laminates of five different thicknesses (1/32 in. to 1/4 in.) from four different suppliers. During the course of the testing, the original manufacturer C was dropped and another substituted because on non-delivery of base material. Copper thickness of both one ounce (0.0014 inch) and two ounce (0.0027 inch) nominal were used on both one and two sides.

The following individual tests were performed:

1. Foil resistivity
2. Solder Dip
3. Peel Strength
4. Volume resistivity
5. Surface resistance
6. Water absorption
7. Dielectric breakdown
8. Dielectric Constant
9. Dissipation factor
10. Flexural Strength
11. Flammability

The basic tests were conducted in accordance with MIL-P-13949B, LP-406B and ASTM B-103.

Standard printing and etching techniques typical of the photo-etch process were used to produce test samples as indicated in Appendix B, and extreme care was exercised to reduce the possibility of specimen contamination to a minimum. After the tests were completed the data was itemized in a suitable manner for evaluation.

6.3 Detailed Data

6.3.1 Literature Survey on Copper Clad Paper Base Epoxy Material

A complete literature survey was made which included the following:

1. Military Specifications
2. Military Standards
3. American Standard of Testing Materials
4. Manufacturers of Paper Epoxy (Copper Clad)
5. Libraries and Government Information Centers

The search indicated that the published data on paper base epoxy was of little value, as far as eliminating any of the tests described in MIL-P-13949B because testing done was not necessarily conducted in accordance with this specification. For this reason, it was decided to perform all of the basic tests required in MIL-P-13949B to establish enough data to add this type of copper-clad laminate material to MIL-P-13949B. Table LXXII includes the published physical properties of laminates from four manufacturers who are producers of paper base epoxy laminating material. These data indicated to what degree each manufacturer's paper base epoxy compares to the other according to their own figures. These data are used to compare the re ults obtained by our own tests on paper base epoxy (Copper Clad). Comparing the various physical properties in Table LXXII, it may be seen that peel strength, solder dip and flammability values for all four laminates are approximately the same. The water absorption of laminator C has a higher value than the other water absorption values. The tests in Table LXXII were reportedly performed in accordance with A.S.T.M. methods by each manufacturer.

TABLE LXXII

Commercial Physical Property Results on Paper Epoxy (PX)

Manufacture of Paper Base Epoxy	Water Absorption (1/16 Inch Thick Laminate)	Peel Strength (Lbs/Inch Thick)	Flammability Test	Solder Dip (1/16 Inch Laminated 500°F Solder)	Copper Resistivity
A	0.30%	8-(1 oz.) 10-(2 oz.)	Self Ext.	10 Sec.	Not Reported
B	0.35%	10-(1 oz.) 11-(2 oz.)	Self Ext.	15 Sec.	Not Reported
C	0.55%	8-(1 oz.) 9-(2 oz.)	Self Ext.	15 Sec.	Not Reported
D	0.38%	8.5-(1 oz.) 13-(2 oz.)	Self Ext.	10 Sec.	Not Reported

6.3.2 Fabrication, Conditioning and Test Procedures

6.3.2.1 Fabrication - All specimens were fabricated in accordance with the procedures outlined in Appendix B.

6.3.2.2 Conditioning and Test Procedure

6.3.2.2.1 Copper Foil Resistivity Conditioning Condition A - The specimen was tested as received with no special conditioning.

Test Procedure

1. Measurement of resistance and temperature - Weight resistivity is the electrical resistance of a body of uniform cross section of unit length and unit weight. In the metric system the units are expressed as "ohm, meter and gram."
The resistance of the specimen was measured with a Leeds and Northrop Kelvin Bridge Ohmeter No. 4285 which has an accuracy of ± 0.15 percent.
Since the resistance of the specimen is affected by the temperature, it was necessary to make sure the variation in temperature was kept within 1° F.
The copper foil specimens, prepared for this test, measured 12 inches by 1/2 inch by .0014 inch. There were two 1 oz. copper strips on a base board of paper base epoxy (13 x 3 x 1/16 inches).
These copper foil strips were produced by etching away 1 oz. copper which was in the unmasked area on the base laminate. The strip pattern was cleaned according to Appendix B. The leads were clamped on each end of the copper strip foil and the resistance was recorded.
(Temperature was read at time of resistance measurement.)

2. Measurement of Weight - T copper foil specimens were weighed per MIL-P-13949B section 4.5.2.3 and also done by electrolytic method. Figure No. 75 shows a Sargent-Slomin electrolytic analyzer which was used in the electrolytic method. Two methods were used to compare the different resistivities of the same specimen. The following procedure was used to determine the weight of the copper foil on the specimens.

   The specimens were carefully inspected for particles of metallic copper, especially along the edges. If copper was present on the edges, it was removed by scraping with a razor blade.

   The specimens were washed with distilled water and placed in a Pyrex tube containing 5 ml of dilute HNO_3 (2 vols concentrated HNO_3 to 3 vols of H_2O).

   This volume was sufficient to cover the entire specimen. At the end of 1/2 hour, the specimen was removed and thoroughly washed, using 25 ml of distilled water.
   This solution was then transferred to a 180 ml electrolytic beaker, the final volume being 40 - 45 ml. After adding 0.8 ml of concentrated NH_4OH, the beaker was placed in the electrodeposition rack. The platinum electrodes used were as follows:

Anode - 52 mesh gauze

Diameter - 18 mm
Height - 15 mm

Cathode - 52 mesh gauze

Diameter - 30 mm
Height - 35 mm

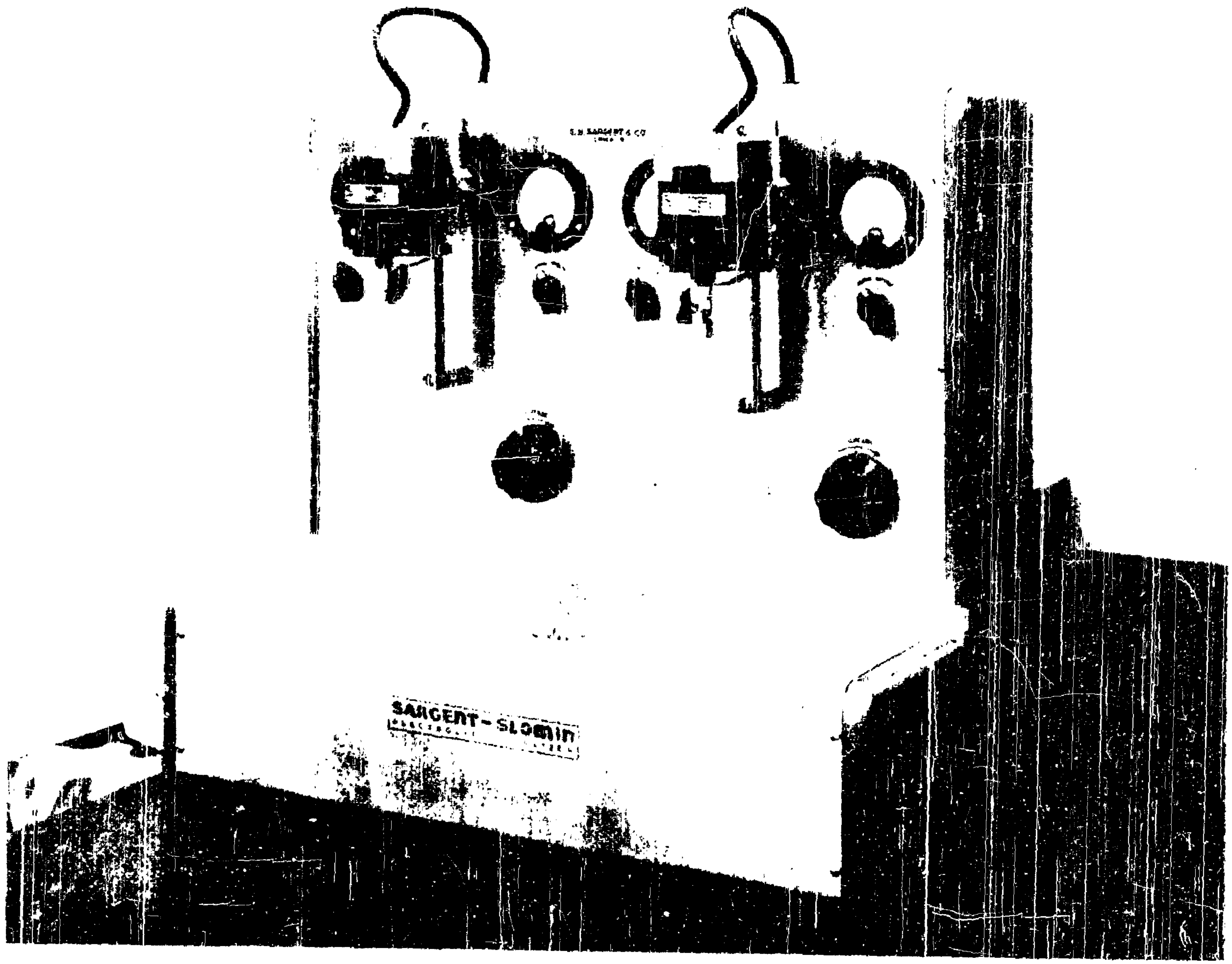


Figure No. 75. - Sargent-Slomin Electrolytic Analyzer For Use In Copper Foil Resistivity Determination

The electrodes were cleaned in dilute HNO_3 and washed with distilled water.
The cathode was then dipped in absolute ethyl alcohol, dried in an oven at 110°C, cooled, and weighed. A microchemical balance with optical lever and special magnetic dampening was used for all weighings. The balance had a sensitivity of 0.001 milligram per scale division.
The cathodes used in the determinations were especially made so as to have a large area with minimum weight. (Approximate weight - 3 grams.)
Special Pyrex supports with electrolytic beakers kept the electrodes located properly. A variable speed Pyrex stirrer was used to agitate the solution. A rectifier was employed as a direct current source. A potential of 2.8 volts was applied for 1 hour at room temperature. At the end of this time the sides of the beaker and the exposed areas of the electrodes were washed down with about 5 ml of distilled water.
Electrolysis was continued for an additional 30 minutes (total 90 minutes). Without breaking the current, the electrodes were thoroughly washed with distilled water as the beaker was slowly lowered. The cathode was dipped in absolute ethyl alcohol, dried in an oven at 110°C, cooled and weighed, and the amount of copper determined by difference.

Three times during the electrolysis, 10-20 milligrams of pure urea was added to the solution.

The cathode was prepared for the next analysis by removing the copper with dilute HNO_3, washing with distilled water, dipping in absolute alcohol, drying and weighing.

3. Measurement of Length - the gage length of the specimen is the distance between the cutting marks on the copper foil caused by the knife marks or the potential clamps. This gage length, L_1 and total length of copper foil strip, L_2, were measured and the values recorded. The copper foil strip was measured to an accuracy of 0.001 inch, using an optical comparator.

4. Calculations - The weight resistivity of the test specimen at a given temperature was calculated as follows:

$$C_W = \frac{W}{L_1 \; L_2} \quad R_x$$

where C_W = weight of test specimen in grams

L_1 = gage length, used to determine R in meters

L_2 = length of test specimen in meters

R_x = measured resistance in ohms

Since the specimens had a uniform cross section, the weight per unit length and the resistance per unit length would be the same over any segmented length of the specimen. Another formula with the temperature correction is as follows:

$$C_{W20} = \frac{R_x}{L_1} \times \frac{W}{L_2} + 0.0006\,(T\text{-}20^\circ\ C)$$

Where T is the measured temperature at time of resistance measurement.

Table LXXIII shows the copper-foil resistivity values of manufacturer A and B calculated by both techniques. As shown, there was very little difference found between using the method of MIL-P-13949B or the electrolytic method. Although some adhesive is removed and weighed with the copper foil as it is peeled off, there was very little difference in the resistivity values, with or without the adhesive. As can be seen from Table LXXIII, the values are approximately 0.0110 ohm-gram/meter square larger than the maximum limit allowed per (0.15940 ohms-gram/meter square) MIL-P-13949B. The possible testing errors were re-checked and no errors could be traced.

TABLE LXXIII

COPPER FOIL RESISTIVITY VALUES OF MANUFACTURERS A AND B

Manufacturer (Copper Clad Both Sides)	Composite Material Thickness (Inches)	Copper Foil Weight (Ounces)	Resistivity Value Per MIL-P-13949B Ohms-(Gram/Meter Square at 20° C	Resistivity Value Per Electrolytic Method-Ohms (Gram/ Meter Square) at 20° C
A	1/16	1 oz.	0.1698	0.1682
A	1/16	1 oz.	0.1708	0.1690
B	1/16	1 oz.	0.1729	0.1710
B	1/16	1 oz.	0.1789	0.1772

6.3.2.2.2 Solder Dip Test

Conditioning

1. Condition A - The specimen was tested as received except cleaning off any dirt, grease, etc., per Appendix B.

Test Procedure

The copper surface of the specimen was cleaned with pumice and cotton, and coated with an activated resin flux. The specimen was then placed foil side down, on the surface of the solder bath at a temperature of 500° F ± 10° F (paper base epoxy solder bath temperature)

Figure No. 76 shows the automatic dip solder machine that was used for the test. Upon removal of the specimen from the solder bath, the specimen was cooled to room temperature (23° C ± 5° C) and examined for blistering or delamination of the foil or laminate. The solder was skimmed prior to dipping in order to remove the surface oxide.

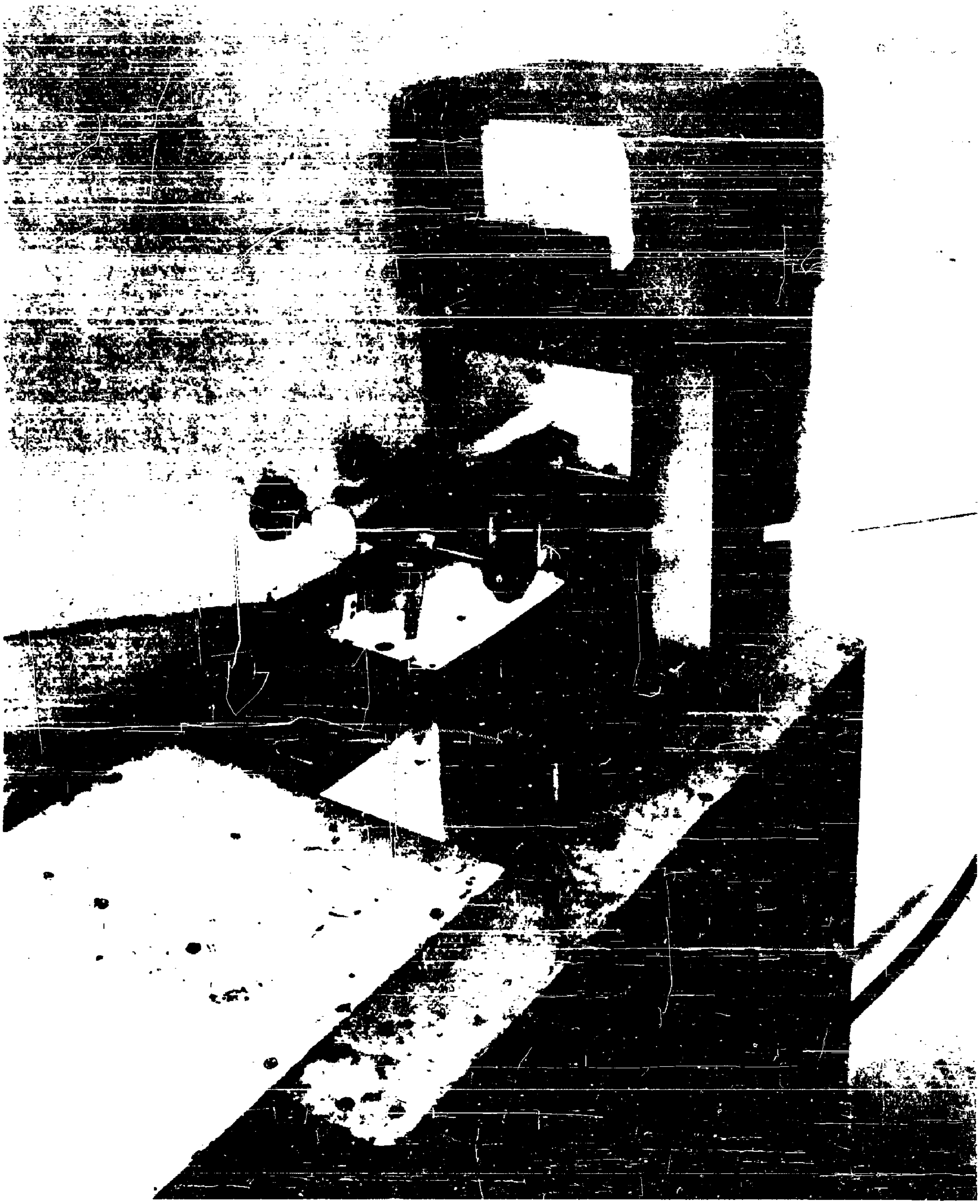


Figure No. 76. - Automatic Dip-Solder Machine

6.3.2.2.3 Peel Strength Test

Conditioning

1. The peel strength was determined for each specimen following the conditioning procedures listed below. Different specimens were used for each of the conditioning cycles. Figure No. 77 shows the Dillon testing machine that was used for the peel strength determined.

a. Ambient Temperature - Condition A - as received.

b. Solder Dip - This conditioning was done per paragraph 3.3.2.2.

c. Elevated Temperature - The specimens were put into an air circulating oven at 140°C for 1 hour. The specimens were then removed and inspected for any blistering or delamination of the copper foil. If there was no blistering or delamination, peel strength measurements were performed.

Figure No. 78 shows the conditioning oven that was used for the elevated temperature conditioning of the specimens.

Test Procedures

1. Measurements

a. The copper foil was stripped from the surface of the laminate sufficiently to allow the installation of the gripping tab, usually about 1/2 inch. The loading rate should not exceed 12 lbs. per minute and the pull speed at 2 ± 1/10 inches per minute.

Figure No. 79 shows the etched 1/8 inch peel strength patterns. The peel strip was 1/8 inch wide and approximately 2 inches long. The test procedure was conducted in accordance with paragraph 4.5.2.5 MIL-P-13949B.

2. Calculations

There are no calculations for this test. The peel strength value was read directly from the testing machine.

6.3.2.2.4 Volume Resistivity and Surface Resistance

Conditioning

1. Sixteen samples from each of three manufacturers were prepared for each of three different thickness of material, 1/16, 3/32 and 1/8 inch. Sample preparation and cleaning was done in accordance with Appendix B. Sample size and configuration was in accordance with paragraph 4.5.2.6 of MIL-P-13949B, except that etched copper rings and bullseyes were used, rather than conductive silver paint.

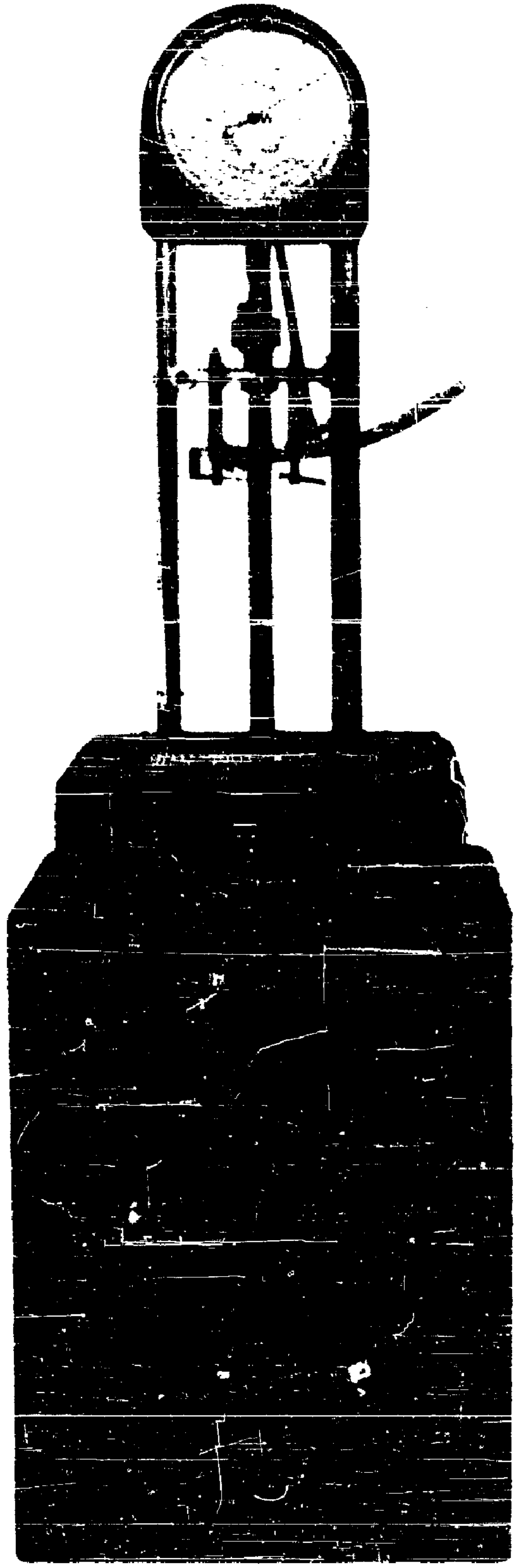


Figure No. 77. Dillon Testing Machine For Peel Strength Determination

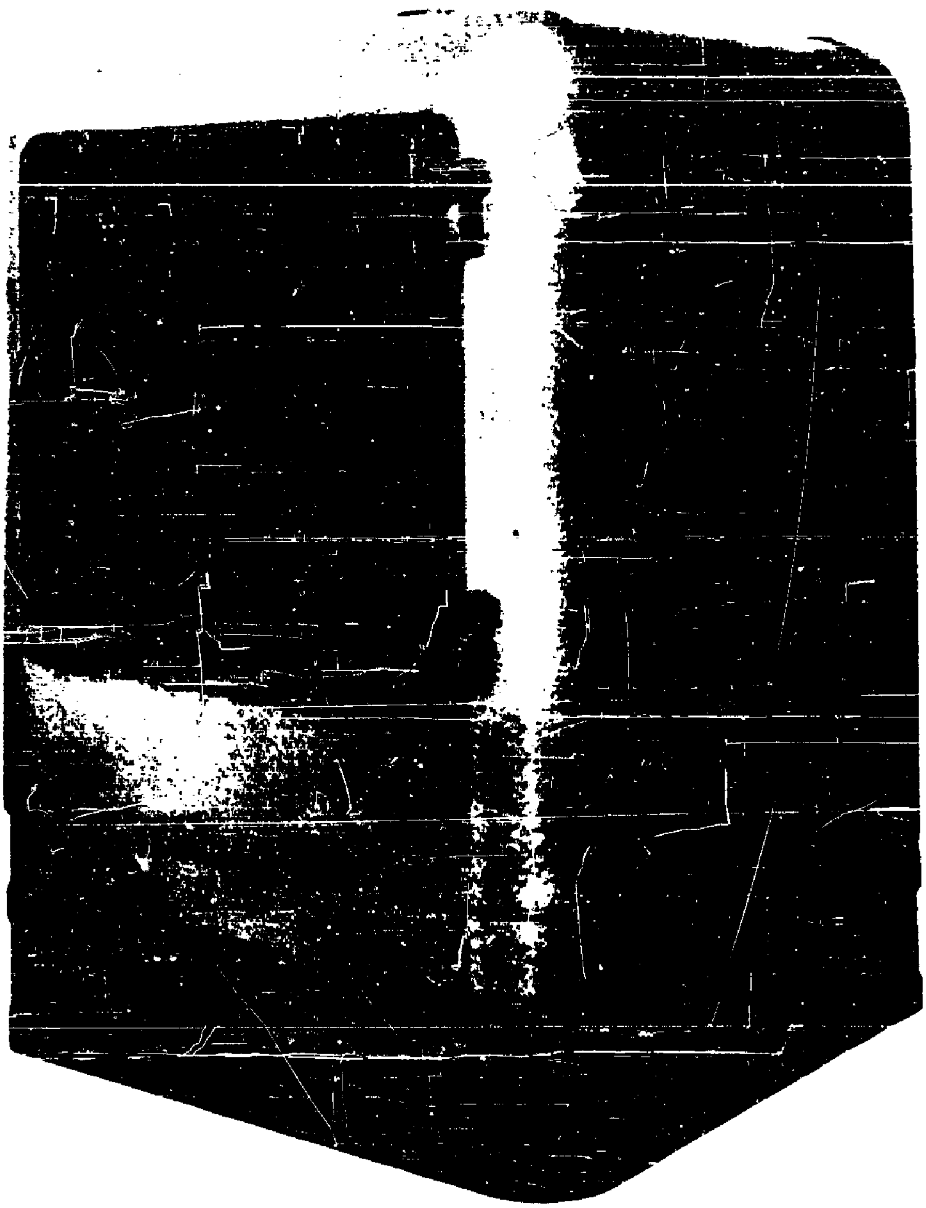


Figure No. 78. Conditioning Oven For Temperature Cycling Of Peel Test Specimens

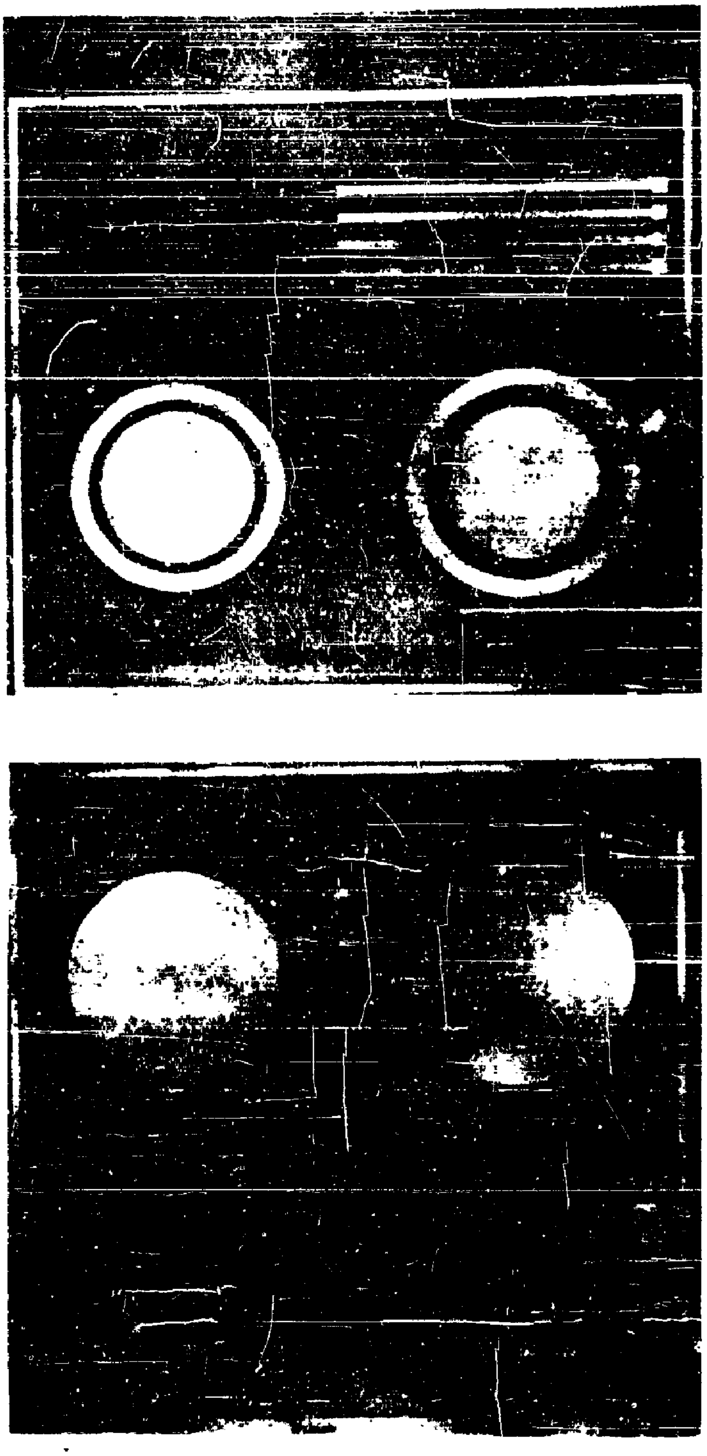


Figure No. 79. Etched Specimen Patterns For Peel Strength, Volume Resistivity And Surface Resistance Tests

Test Procedure

1. Samples were placed in the modified humidity chamber in the same manner as detailed earlier for measuring the insulation resistance values for Task B.

2. After conditioning in the chamber, in accordance with MIL-P-13949B, measurements of surface and volume resistance were made using the same equipment, and the same techniques outlined in Task B.

3. Volume resistivity was calculated as follows:

$$r = \frac{RA}{L}$$

where:
r = volume resistivity in megohmcentimeters

R = measured volume resistance in megohms

A = area of guarded electrode in square centimeters

L = average thickness of specimen in centimeters

4. Surface resistance was measured in megohms.

6.3.2.3 Water Absorption Test

Conditioning

1. At least four specimens per thickness of the specified material to be tested were required for this test. After all the specimens were machined smooth on the edges, they were dried in an oven for 1 hour at + 6 - 0 minutes at 105^{o} C ± 2^{o} C.

Test Procedure

1. Measurements

a. After conditioning of the specimens, they were cooled in a desiccator at 23^{o} C ± 5^{o} C for 16 to 20 hours and immediately weighed upon removal to 0.0001 grams. The dimensions of the specimens were measured with a micrometer. The specimens were then immersed in distilled water maintained at a temperature of 23^{o} C ± 2^{o} C. At least 50 ml of distilled water was employed for immersing each specimen. After an immersion of 24 hours + 1/2 hour - 0 hours, each specimen was removed from the water, the surface moisture quickly absorbed by a dry cloth, and the specimen reweighed. The test was conducted in accordance with L-P-406B, method 7031. Figure No. 80 shows the laboratory balance where the specimens were weighed.

2. Calculations

a. The percentage increase in weight after immersion calculated to the nearest 0.01 percent was calculated as follows:

Increase in weight, % =

$$\frac{\text{New weight } (W_2) - \text{conditioned weight } (W_1) \times 100}{\text{Conditioned weight } (W_1)}$$

$$\frac{W_2 - W_1 \times 100}{W_1}$$

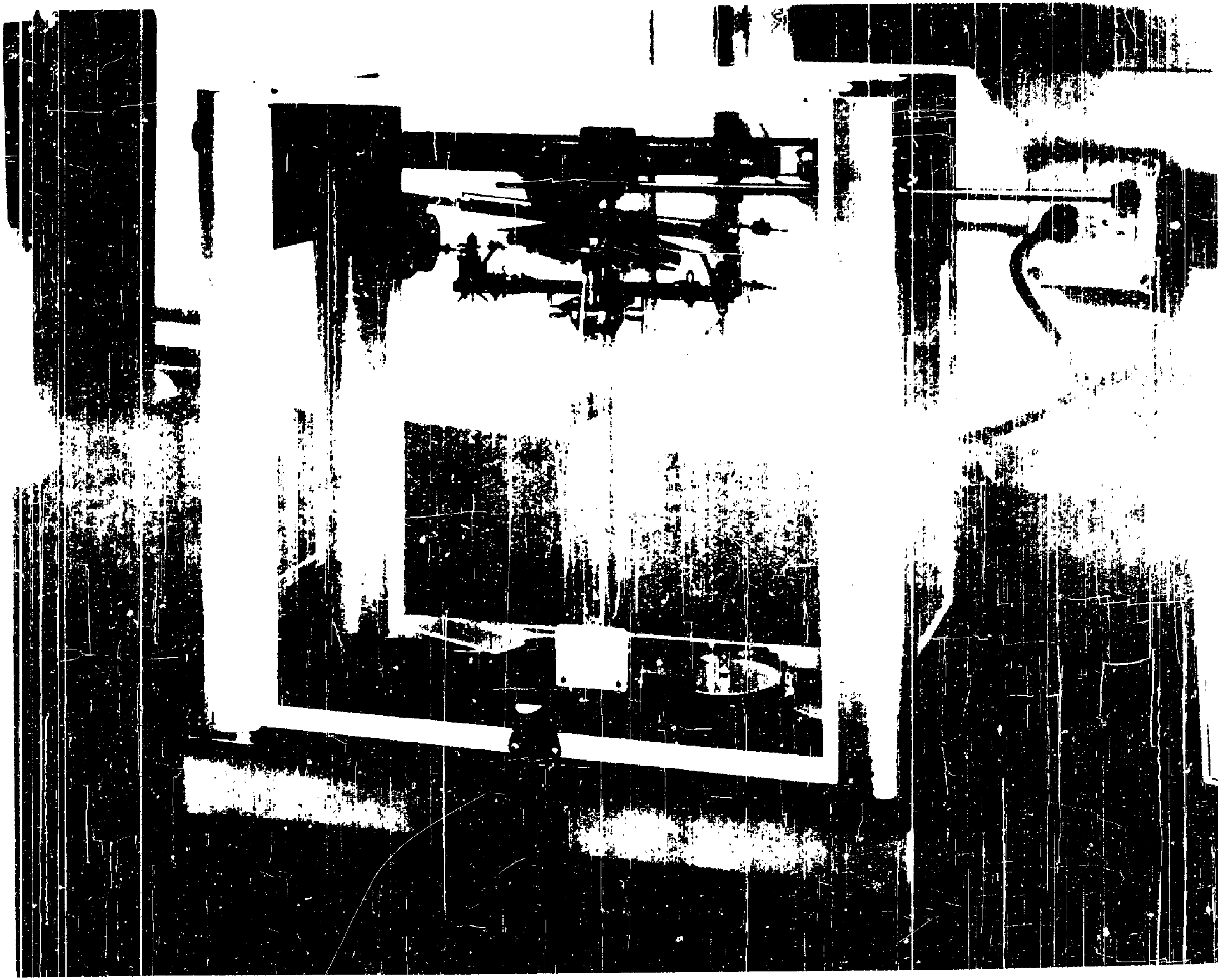


Figure No. 80. Laboratory Balance For Use In Weighing Water Absorption Specimens

6.3.2.4 Dielectric Breakdown

Conditioning

1. All specimens were tested with the copper foil removed. Prior to conditioning, specimens were cleaned with a soft rag and isopropyl alcohol.

2. Specimens for all tests were conditioned for 48 hours in distilled water at 50°C (D 48/50) and cooled for 1/2 hour at 23°C (D 1/2/23°C). Conditioning and testing were scheduled in such a way that all specimens were removed from the elevated temperature bath within the scheduled tolerance of plus 2 hours and from the room temperature bath within the specified tolerance of plus 1/2 hour.

3. Measurements
All measurements were taken following the step-by-step test in method 4031 of LP-406 and section 4.5.2.8.2.2 of MIL-P-13949B. Figure 81 shows the dielectric breakdown test setup and Figure 82 shows the dielectric breakdown specimen with electrodes.

6.3.2.5. Dielectric Constant and Dissipation Factor Test

1. Conditioning

Dielectric constant and dissipation factor determination were made by the standard procedures as outlined in LP 406, Method 4021, as modified by MIL-P-13949B, paragraph 4.5.2.9. Eelectrodes were painted on both sides of each specimen using Du Pont No. 4817 silver conductive paint. (An equivalent conductive paint could be used). The 1/32 and 1/16 inch specimens had 2 inch diameter electrodes painted on one side and 3 inch diameter electrodes painted on the other side. The 3/32, 1/8, and 1/4 inch specimens had 3 inch diameter electrodes painted on one side and 4 inch diameter electrodes painted on the other side.

2. Measurements and Calculations

Values of capacitance and Q were obtained for each specimen using a Boonton Q Meter, the values of dielectric constant were then calculated from the following relations:

$$K = \frac{C - C_f}{C_d + C_v}$$

K = Dielectric constant of the material.

C = Measured capacitance of the specimen.

C_d & C_f = Edge correction for electrodes of unequal size as defined by equations 31, paragraph 14.d of ASTM D150-54T.

C_v = Equivalent vacuum capacitance using the same electrode geometry.

$$D = \frac{C_1 \times Q}{Q_1 \times C \times Q_2}$$

C_1 = Capacitance of instrument tuned without the specimen.

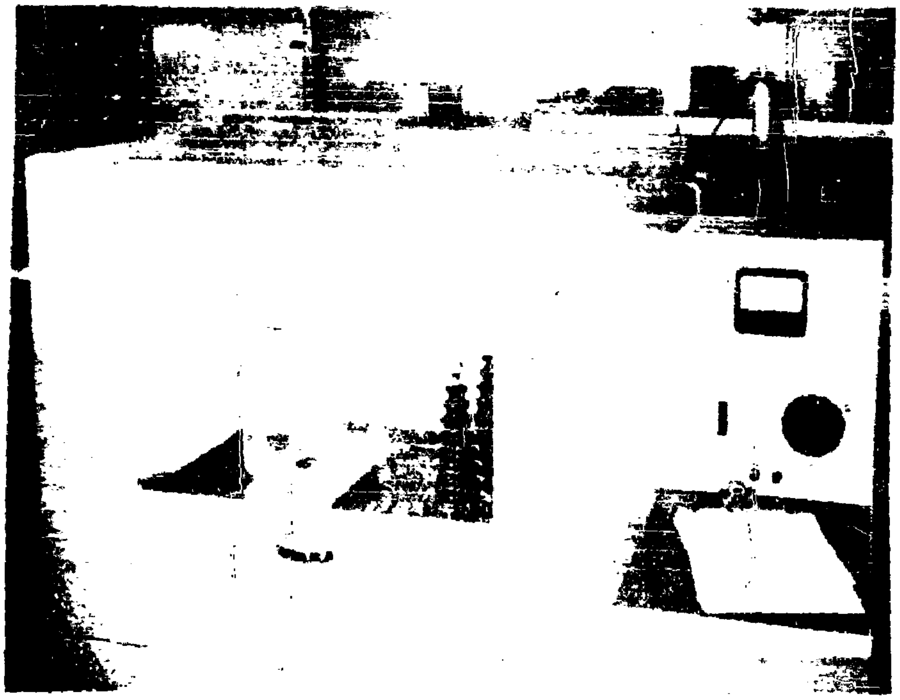


Figure No. 81. Dielectric Breakdown Test Setup

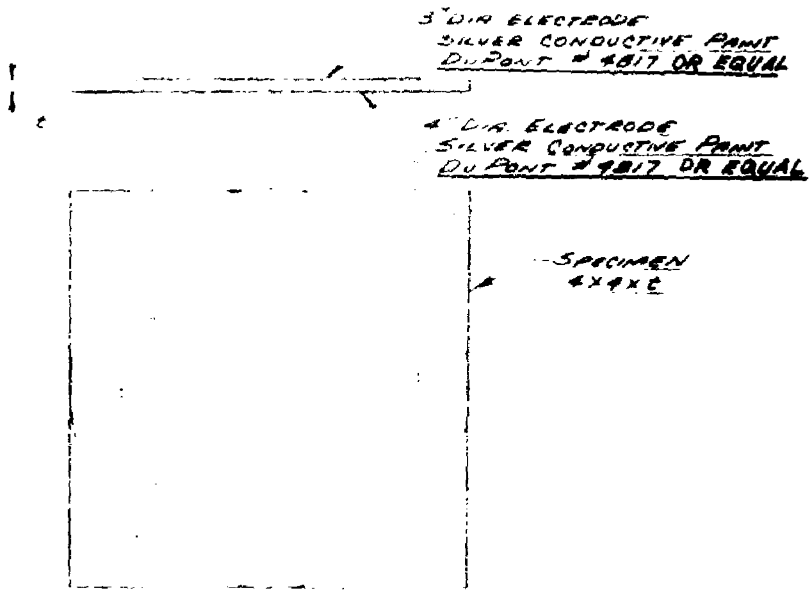


Figure No. 82. Dielectric Constant And Dissipation Factor Specimen With Electrodes

C_2 = Capacitance of instrument tuned with the specimen.

C = Capacitance of the specimen $(C_1 - C_2)$.

Q_1 = Q of the instrument tuned without the specimen.

Q_2 = Q of the instrument tuned with the specimen.

Q = Change in Q $(Q_1 - Q_2)$

Specimens were 4 by 4 inches by the thickness. Electrodes were painted on the specimens and allowed to air dry a minimum of 96 hours prior to conditioning.

Figure 83 shows the dielectric constant and dissipation factor test set up.

Figure 84 shows the specimen with electrodes for these two electrical test determinations.

6.3.2.6 Flexure Test

1. Conditioning - The copper was removed from all specimens by etching.

2. Test Procedure - 16 specimens from each of three vendors were tested for material thickness of 1/32 in., 1/16 in., 3/32 in., 1/8 in. and 1/4 in. Eight specimens were cut from the crosswise direction and 8 lengthwise. Sample size was in accordance with Table XI of MIL-P-13949B.

   Tests were conducted on Flexure Test Machine illustrated in Figure 85.

6.3.2.7 Flammability Test

Conditioning

1. The specimen was tested in the as received condition.

Test Procedure

1. Dimensions - At least three specimens were cut to 6 inches in length by 0.5 inch in width by the thickness. The copper foil was etched and cleaned according to Appendix B.

2. Positioning of Specimen - The conditioned specimen was marked by scribing two lines 1 inch and 5 inches from one end of the specimen. The specimen was then clamped in a support at the end farthest from the 1-inch mark with its longitudinal axis horizontal and its transverse axis inclined at 45^0 to the horizontal. Under the test specimen there was a piece of 20-mesh bunsen burner gauze about 5 inches square in a horizontal position 1/4 inch below the edge of the specimen, with 1/2 inch of the specimen extending beyond the edge of the gauze.

3. Ignition of Specimen - A Bunsen burner with a flame 1/2 to 3/4 inch in height was placed under the free end of the test specimen and adjusted so the flame tip was just in contact with the specimen. At the end of 30 seconds the flame was removed and the specimen allowed to burn. A stop watch was used to time the flame when it reached the first mark on

Figure No. 83. Dielectric Constant And Dissipation Factor Test Setup

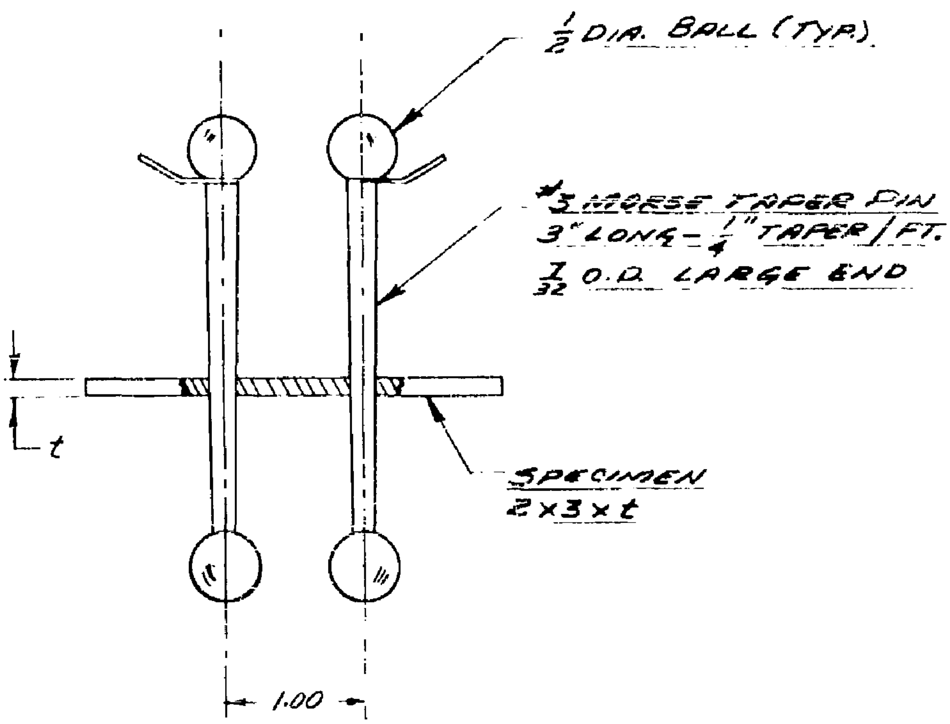


Figure No. 84. Dielectric Breakdown Specimen With Electrodes

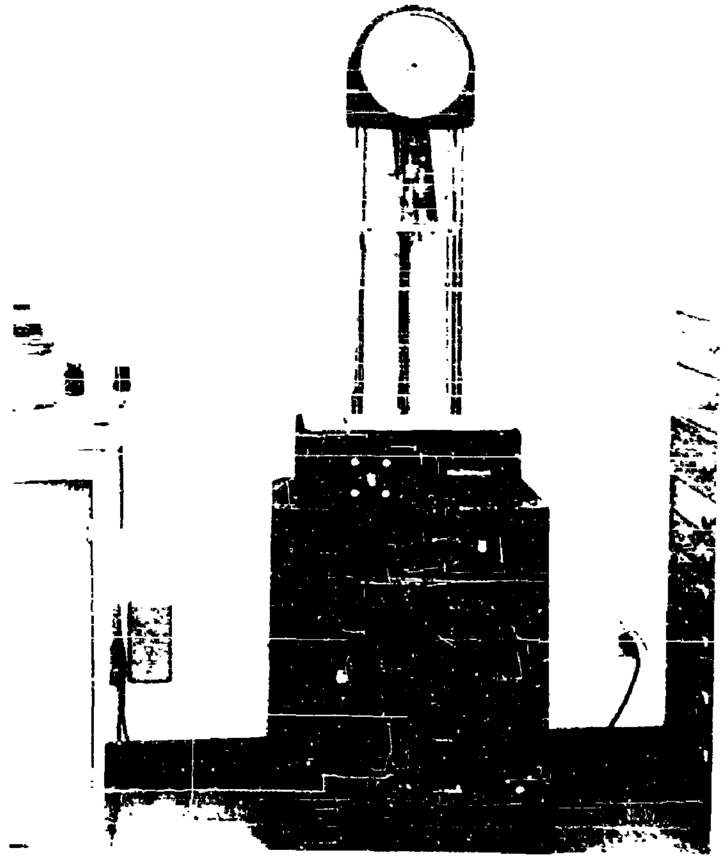


Figure No. 85. Flexure Test Machine

the specimen and time observed when the flame reached the 4-inch mark. SPECIMEN When the ~~plastic~~ did not continue to burn after the first ignition, the burner was placed under the free end for a second period of 30 seconds immediately following the extinction of the flame. When the specimen did not continue to burn to the 4-inch mark after the second ignition, the specimen was reported self-extinguishing. Figure No. 86 shows the flammability test setup.

6.4 Analysis of Results

6.4.1 Foil Resistivity

Table LXXIII (page ~~212~~ 211) reports the results of 1 and 2 ounce copper foil resistivities. As it can be seen in Table LXXIII, the resistivity values performed per MIL-P-13949B holds a greater value for 1 and 2 ounce copper than is stated in MIL-P-13949B. Not all of the resistivity values performed by the electrolytic method are reported. It was decided to discontinue running the electrolytic method because Task E of the contract is only concerned with MIL-P-13949B test procedures. It would appear that the resistivity values tested by the electrolytic method does not vary from the reported resistivities performed per MIL-P-13949B. The averages reported for each vendor source in Table LXXIV are in turn averaged and one value reported for copper resistivity in Table LXXIII.

6.4.2 Solder Dip

All of the copper-clad paper-base epoxy laminates tested showed no blisters or delaminations of either the copper foil or laminate itself.

Figure No. 86 Flammability Test Set Up

TABLE I-XXIV

COPPER FOIL RESISTIVITY VALUES OF MANUFACTURERS A, B AND D

Manufacturer (Copper Clad Both Sides)	Composite Material Thickness (Inch)	Copper Foil Weight (Ounces)	Resistivity Value Per MIL-P 13949B Ohms-(Gram Meter Square) At 20 C	Resistivity Value Per Electrolytic Method-Ohms (Gram Meter Square) At 20 C
A	1/16	1 oz.	0.1698	0.1687
A	1/16	1 oz.	0.1708	0.1690
A	1/16	1 oz.	0.1698	-----
A	1/16	1 oz.	0.1692	-----
A	3/32	2 oz.	0.1750	-----
A	3/32	2 oz.	0.1696	-----
A	3/32	2 oz.	0.1714	-----
A	3/32	2 oz.	0.1723	-----
	Average Value		0.1709	
B	1/16	1 oz.	0.1729	0.1710
B	1/16	1 oz.	0.1789	0.1772
B	1/16	1 oz.	0.1676	-----
B	1/16	1 oz.	0.1692	-----
B	3/32	2 oz.	0.1724	-----
B	3/32	2 oz.	0.1750	-----
B	3/32	2 oz.	0.1730	-----
B	3/32	2 oz.	0.1755	-----
	Average Value		0.1731	
D	1/16	1 oz.	0.1723	-----
D	1/16	1 oz.	0.1723	-----
D	1/16	1 oz.	0.1756	-----
D	1/16	1 oz.	0.1704	-----
D	3/32	2 oz.	0.1717	-----
D	3/32	2 oz.	0.1715	-----
D	3/32	2 oz.	0.1717	-----
D	3/32	2 oz.	0.1732	-----
	Average Value		0.1723	

The materials included the following:

1. Manufacture A, B and C sources

   a. 1/16 inch - 1 oz. copper clad both sides

   b. 3/32 inch - 2 oz. copper clad both sides

   c. Base laminate material was paper base epoxy.

   The test procedure has been described in paragraph 6.3.2.2.2.

6.4.3 Peel Strength

The specimens were conditioned and tested according to paragraph 6.3.2.2.3. Tables LXXV to LXXXIX show the peel strength results of manufacturer A, B and D. The after solder dip, temperature cycling and elevated temperature conditions had very little effect on the 1 and 2 ounce copper peel strips. The 1 oz. copper values averaged around 10 lbs. per inch width while the 2 oz. copper values averaged 13.5 lbs. per inch width. These values represent averaged values of all three vendors A, B and D.

6.4.4 Volume Resistivity and Surface Resistance

Tables XC to XCIV show the test results of volume resistivity and surface resistance on paper base epoxy. The test procedure was performed per MIL-P-13949B. Values which were too high or low with respect to the overall values reported were not averaged. It should be noted that Vendor A's resistance values were lower than those of Vendors B and D. One reason for this could be in variation of resistance per lot of material for this type of paper epoxy laminate.

6.4.5 Water Absorption

The test procedure has been described in paragraph 6.3.2.3 in the report. Tables XCV to XCVIII give the water absorption results of manufacturers A, B and D respectively. The results showed consistent values for all three tables. The following percent absorption values are averages of (16 samples) of both 1/16 and 3/32 inch material of manufacturers A, B and D.

Manufacturer	A	B	D
1/16 inch - 1 oz.	.49%	.44%	.58%
3/32 inch - 2 oz.	.35%	.29%	.35%

It is interesting to note that the 1/16 inch - 1 oz. laminate of manufacturer D percent absorption value is about the same as reported in Table I on page 8. The commercially published percent absorption value of manufacturer D is .55% for 1/16 inch laminate.

6.4.6 Dielectric Breakdown

These tests were performed by the Delsen Corporation of Glendale, California for U.S. Engineering Company. Tables XCIX to CI show the dielectric breakdown test results of Vendors A, B and D on paper epoxy laminate.

TABLE LXXV

PEEL STRENGTH OF MANUFACTURER A (1/32 INCH THICKNESS)

Paper Base Epoxy Laminate

Specimen Number	Composite Material Thickness (Inch)	Copper Clad	Copper Foil Weight (Ounces)	After Solder Dip (Lbs/Inch Width)	After Temperature Cycling (Lbs/Inch Width)	After Elevated Temperature (Lbs/Inch Width)	Condition A (Lbs/Inch Width)
1	1/32	1 Side	1 oz.	10.0	11.0	11.0	12.0
2	1/32	1 Side	1 oz.	10.5	10.5	10.5	12.0
3	1/32	1 Side	1 oz.	10.0	10.5	11.0	11.0
4	1/32	1 Side	1 oz.	10.5	10.5	11.0	11.5
5	1/32	1 Side	1 oz.	11.0	11.0	11.0	11.0
6	1/32	1 Side	1 oz.	10.0	11.0	11.0	11.5
7	1/32	1 Side	1 oz.	11.0	11.0	10.5	11.5
8	1/32	1 Side	1 oz.	10.5	11.0	11.0	12.0
Average Peel Strength Values				10.4	10.8	10.9	11.7
9	1/32	1 Side	2 oz.	13.0	15.0	16.5	16.0
10	1/32	1 Side	2 oz.	14.0	15.5	15.0	17.0
11	1/32	1 Side	2 oz.	11.5	15.5	17.5	16.5
12	1/32	1 Side	2 oz.	11.0	15.5	17.0	15.5
13	1/32	1 Side	2 oz.	12.5	15.0	16.0	16.5
14	1/32	1 Side	2 oz.	12.5	15.5	18.0	18.0
15	1/32	1 Side	2 oz.	11.5	14.5	16.0	16.5
16	1/32	1 Side	2 oz.	11.5	14.5	17.0	16.5
Average Peel Strength Values				12.2	15.1	16.6	16.5

TABLE LXXVI

PEEL STRENGTH OF MANUFACTURER B (1/32 INCH THICKNESS)

Paper Base Epoxy Laminate

1	1/32	1 Side	1 oz.	9.5	10.0	10.0	10.0
2	1/32	1 Side	1 oz.	9.5	10.0	10.0	10.0
3	1/32	1 Side	1 oz.	10.0	10.0	9.0	9.5
4	1/32	1 Side	1 oz.	10.0	9.0	9.0	9.5
5	1/32	1 Side	1 oz.	10.0	9.5	9.5	10.0
6	1/32	1 Side	1 oz.	10.0	10.0	10.0	10.0
7	1/32	1 Side	1 oz.	9.0	9.5	10.0	9.5
8	1/32	1 Side	1 oz.	10.0	10.0	10.0	10.0
Average Peel Strength Values				9.8	9.8	9.7	9.8
9	1/32	1 Side	2 oz.	14.5	14.5	14.0	15.0
10	1/32	1 Side	2 oz.	14.0	14.5	14.0	14.5
11	1/32	1 Side	2 oz.	14.0	14.5	14.0	15.0
12	1/32	1 Side	2 oz.	14.5	14.5	14.0	15.0
13	1/32	1 Side	2 oz.	14.0	14.5	14.0	15.0
14	1/32	1 Side	2 oz.	14.5	14.5	14.0	15.0
15	1/32	1 Side	2 oz.	14.0	14.5	13.5	15.0
16	1/32	1 Side	2 oz.	15.0	14.5	14.0	15.5
Average Peel Strength Values				14.3	14.5	14.0	15.0

TABLE LXXVII

PEEL STRENGTH OF MANUFACTURER D (1/32 INCH THICKNESS)

Paper Base Epoxy Laminate

Specimen Number	Composite Material Thickness (Inch)	Copper Clad	Copper Foil Weight (Ounces)	After Solder Dip (Lbs/Inch Width)	After Temperature Cycling (Lbs/Inch Width)	After Elevated Temperature (Lbs/Inch Width)	Condition A (Lbs/Inch Width)
1	1/32	1 Side	1 oz.	10.2	9.5	10.0	10.5
2	1/32	1 Side	1 oz.	10.5	10.0	9.5	10.5
3	1/32	1 Side	1 oz.	10.5	10.0	10.0	10.0
4	1/32	1 Side	1 oz.	10.0	10.0	10.0	10.0
5	1/32	1 Side	1 oz.	10.5	10.0	9.5	10.0
6	1/32	1 Side	1 oz.	9.5	9.5	10.0	10.0
7	1/32	1 Side	1 oz.	10.0	10.5	10.0	9.5
8	1/32	1 Side	1 oz.	9.5	9.5	9.5	10.0
Average Peel Strength Values				10.1	10.0	9.8	10.1
9	1/32	1 Side	2 oz.	12.0	15.5	14.0	14.5
10	1/32	1 Side	2 oz.	12.0	15.0	13.5	15.5
11	1/32	1 Side	2 oz.	12.5	15.0	14.0	15.0
12	1/32	1 Side	2 oz.	12.0	15.0	13.0	14.0
13	1/32	1 Side	2 oz.	12.5	15.5	13.5	16.0
14	1/32	1 Side	2 oz.	13.5	14.0	14.0	15.5
15	1/32	1 Side	2 oz.	11.0	13.5	13.5	16.0
16	1/32	1 Side	2 oz.	15.0	13.5	14.5	15.0
Average Peel Strength Values				12.6	14.6	13.7	15.2

TABLE LXXVIII

PEEL STRENGTH OF MANUFACTURER A (1/16 INCH THICKNESS)

Paper Base Epoxy Laminate

Specimen Number	Composite Material Thickness (Inch)	Copper Clad	Copper Foil Weight (Ounces)	After Solder Dip (Lbs/Inch Width)	After Temperature Cycling (Lbs/Inch Width)	After Elevated Temperature (Lbs/Inch Width)	Condition A (Lbs/Inch Width)
1	1/16	2 Sides	1 oz.	-----	10.4	-----	-----
2	1/16	2 Sides	1 oz.	-----	11.0	-----	-----
3	1/16	2 Sides	1 oz.	-----	10.4	-----	-----
4	1/16	2 Sides	1 oz.	-----	10.0	-----	-----
5	1/16	2 Sides	1 oz.	-----	10.4	-----	-----
6	1/16	2 Sides	1 oz.	-----	11.0	-----	-----
7	1/16	2 Sides	1 oz.	-----	10.5	-----	-----
8	1/16	2 Sides	1 oz.	-----	10.8	-----	-----
9	1/16	2 Sides	1 oz.	-----	11.5	-----	-----
10	1/16	2 Sides	1 oz.	-----	11.0	-----	-----
11	1/16	2 Sides	1 oz.	-----	10.5	-----	-----
12	1/16	2 Sides	1 oz.	-----	10.5	-----	-----
13	1/16	2 Sides	1 oz.	-----	10.4	-----	-----
14	1/16	2 Sides	1 oz.	-----	11.0	-----	-----
15	1/16	2 Sides	1 oz.	-----	10.4	-----	-----
16	1/16	2 Sides	1 oz.	-----	10.4	-----	-----
Average Peel Strength Values					10.6		
17	1/16	2 Sides	2 oz.	16.0	16.0	15.5	17.0
18	1/16	2 Sides	2 oz.	16.0	16.0	16.5	17.5
19	1/16	2 Sides	2 oz.	16.0	17.0	17.5	16.0
20	1/16	2 Sides	2 oz.	16.0	17.0	18.0	18.0
21	1/16	2 Sides	2 oz.	16.0	18.0	17.0	18.0
22	1/16	2 Sides	2 oz.	17.0	18.0	17.0	18.0
23	1/16	2 Sides	2 oz.	16.0	16.0	15.5	17.0
24	1/16	2 Sides	2 oz.	17.0	17.0	17.0	16.5
25	1/16	2 Sides	2 oz.	17.0	18.0	17.0	17.5
26	1/16	2 Sides	2 oz.	17.0	17.0	17.0	17.0
27	1/16	2 Sides	2 oz.	16.0	16.0	16.0	18.0
28	1/16	2 Sides	2 oz.	16.0	16.0	17.0	18.0
29	1/16	2 Sides	2 oz.	17.0	17.0	16.0	18.0
30	1/16	2 Sides	2 oz.	17.0	16.0	17.0	17.0
31	1/16	2 Sides	2 oz.	17.0	16.0	17.0	17.0
32	1/16	2 Sides	2 oz.	16.0	16.0	16.0	17.0
Average Peel Strength Values				16.4	16.7	16.7	17.3

TABLE LXXIX

PEEL STRENGTH OF MANUFACTURER B (1/16 INCH THICKNESS)

Paper Base Epoxy Laminate

Specimen Number	Composite Material Thickness (Inch)	Copper Clad	Copper Foil Weight (Ounces)	After Solder Dip (Lbs/Inch Width)	After Temperature Cycling (Lbs/Inch Width)	After Elevated Temperature (Lbs/Inch Width)	Condition A (Lbs/Inch Width)
1	1/16	2 Sides	1 oz.	-----	8.4	-----	-----
2	1/16	2 Sides	1 oz.	-----	8.8	-----	-----
3	1/16	2 Sides	1 oz.	-----	8.8	-----	-----
4	1/16	2 Sides	1 oz.	-----	9.5	-----	-----
5	1/16	2 Sides	1 oz.	-----	10.0	-----	-----
6	1/16	2 Sides	1 oz.	-----	8.8	-----	-----
7	1/16	2 Sides	1 oz.	-----	9.5	-----	-----
8	1/16	2 Sides	1 oz.	-----	8.4	-----	-----
9	1/16	2 Sides	1 oz.	-----	8.8	-----	-----
10	1/16	2 Sides	1 oz.	-----	8.8	-----	-----
11	1/16	2 Sides	1 oz.	-----	8.8	-----	-----
12	1/16	2 Sides	1 oz.	-----	8.8	-----	-----
13	1/16	2 Sides	1 oz.	-----	9.0	-----	-----
14	1/16	2 Sides	1 oz.	-----	10.0	-----	-----
15	1/16	2 Sides	1 oz.	-----	8.8	-----	-----
16	1/16	2 Sides	1 oz.	-----	8.4	-----	-----
Average Peel Strength Values					8.9		
17	1/16	2 Sides	2 oz.	14.0	13.0	14.0	17.0
18	1/16	2 Sides	2 oz.	15.0	16.0	15.0	16.0
19	1/16	2 Sides	2 oz.	14.0	13.5	13.5	17.0
20	1/16	2 Sides	2 oz.	15.0	13.5	13.5	16.0
21	1/16	2 Sides	2 oz.	15.0	13.5	14.0	18.0
22	1/16	2 Sides	2 oz.	14.0	14.0	14.0	15.0
23	1/16	2 Sides	2 oz.	15.0	14.0	14.0	14.0
24	1/16	2 Sides	2 oz.	14.0	14.0	13.0	15.0
25	1/16	2 Sides	2 oz.	15.0	13.0	16.0	15.0
26	1/16	2 Sides	2 oz.	15.0	14.0	15.0	14.0
27	1/16	2 Sides	2 oz.	13.0	13.0	14.0	15.0
28	1/16	2 Sides	2 oz.	13.0	13.0	13.0	16.0
29	1/16	2 Sides	2 oz.	13.0	14.0	14.0	17.0
30	1/16	2 Sides	2 oz.	14.0	14.0	15.0	15.0
31	1/16	2 Sides	2 oz.	14.0	14.0	13.0	15.0
32	1/16	2 Sides	2 oz.	14.0	14.0	13.0	15.0
Average Peel Strength Values				14.2	13.8	14.0	15.6

TABLE LXXX

PEEL STRENGTH OF MANUFACTURER D (1/16 INCH THICKNESS)

Paper Base Epoxy Laminate

Specimen Number	Composite Material Thickness (Inch)	Copper Clad	Copper Foil Weight (Ounces)	After Solder Dip (Lbs/Inch Width)	After Temperature Cycling (Lbs/Inch Width)	After Elevated Temperature (Lbs/Inch Width)	Condition A (Lbs/Inch Width)
1	1/16	2 Sides	1 oz.	10.0	10.0	10.0	10.0
2	1/16	2 Sides	1 oz.	10.2	11.0	10.2	10.4
3	1/16	2 Sides	1 oz.	10.0	10.5	10.0	10.0
4	1/16	2 Sides	1 oz.	10.0	10.0	10.4	10.0
5	1/16	2 Sides	1 oz.	10.2	10.0	10.4	10.4
6	1/16	2 Sides	1 oz.	10.0	10.0	10.0	10.0
7	1/16	2 Sides	1 oz.	10.0	10.5	10.2	10.4
8	1/16	2 Sides	1 oz.	10.0	10.0	10.0	10.0
9	1/16	2 Sides	1 oz.	11.4	10.5	11.2	11.6
10	1/16	2 Sides	1 oz.	11.6	11.0	12.0	12.0
11	1/16	2 Sides	1 oz.	11.6	10.5	12.0	12.0
12	1/16	2 Sides	1 oz.	10.0	11.0	10.4	10.4
13	1/16	2 Sides	1 oz.	11.0	10.5	11.4	11.6
14	1/16	2 Sides	1 oz.	11.2	11.5	11.6	11.6
15	1/16	2 Sides	1 oz.	10.4	11.0	10.4	10.4
16	1/16	2 Sides	1 oz.	11.0	10.0	11.0	11.0
Average Peel Strength Values				10.5	10.5	10.7	10.7
17	1/16	2 Sides	2 oz.	13.0	14.0	13.0	14.0
18	1/16	2 Sides	2 oz.	14.0	13.5	13.0	14.0
19	1/16	2 Sides	2 oz.	13.0	14.0	12.0	13.0
20	1/16	2 Sides	2 oz.	13.0	14.0	14.0	11.0
21	1/16	2 Sides	2 oz.	14.0	12.5	12.5	15.0
22	1/16	2 Sides	2 oz.	14.0	13.5	12.5	15.0
23	1/16	2 Sides	2 oz.	13.0	13.0	12.0	14.0
24	1/16	2 Sides	2 oz.	13.5	14.0	13.0	14.0
25	1/16	2 Sides	2 oz.	14.5	13.0	14.0	14.0
26	1/16	2 Sides	2 oz.	14.5	13.0	13.0	15.0
27	1/16	2 Sides	2 oz.	13.5	13.5	12.5	15.0
28	1/16	2 Sides	2 oz.	13.0	14.0	13.0	14.0
29	1/16	2 Sides	2 oz.	13.0	14.0	13.0	14.0
30	1/16	2 Sides	2 oz.	14.0	13.0	13.5	15.0
31	1/16	2 Sides	2 oz.	13.0	13.0	13.0	15.0
32	1/16	2 Sides	2 oz.	14.0	14.0	12.5	15.0
Average Peel Strength Values				13.6	13.5	12.9	14.5

TABLE LXXXI

PEEL STRENGTH OF MANUFACTURER A (3/32 INCH THICKNESS)

Paper Base Epoxy Laminate

Specimen Number	Composite Material Thickness (Inch)	Copper Clad	Copper Foil Weight (Ounces)	After Solder Dip (Lbs/Inch Width)	After Temperature Cycling (Lbs/Inch Width)	After Elevated Temperature (Lbs/Inch Width)	Condition A (Lbs/Inch Width)
1	3/32	2 Sides	1 oz.	10.0	11.0	11.0	12.0
2	3/32	2 Sides	1 oz.	10.0	10.0	12.0	10.0
3	3/32	2 Sides	1 oz.	9.0	9.0	11.0	11.0
4	3/32	2 Sides	1 oz.	9.0	9.0	12.0	12.0
5	3/32	2 Sides	1 oz.	10.0	10.0	11.0	10.0
6	3/32	2 Sides	1 oz.	10.0	9.0	11.0	10.0
7	3/32	2 Sides	1 oz.	10.0	10.0	12.0	11.0
8	3/32	2 Sides	1 oz.	10.0	10.0	12.0	12.0
9	3/32	2 Sides	1 oz.	9.0	9.0	11.0	11.0
10	3/32	2 Sides	1 oz.	9.0	10.0	12.0	11.0
11	3/32	2 Sides	1 oz.	10.0	9.0	11.0	12.0
12	3/32	2 Sides	1 oz.	9.0	9.0	10.0	12.0
13	3/32	2 Sides	1 oz.	10.0	11.0	11.0	11.0
14	3/32	2 Sides	1 oz.	10.0	9.0	11.0	10.0
15	3/32	2 Sides	1 oz.	9.0	10.0	11.0	11.0
16	3/32	2 Sides	1 oz.	9.0	9.0	11.0	11.0
Average Peel Strength Values				9.5	9.6	11.2	11.1
17	3/32	2 Sides	2 oz.	-----	16.0	-----	-----
18	3/32	2 Sides	2 oz.	-----	18.0	-----	-----
19	3/32	2 Sides	2 oz.	-----	18.0	-----	-----
20	3/32	2 Sides	2 oz.	-----	18.8	-----	-----
21	3/32	2 Sides	2 oz.	-----	17.0	-----	-----
22	3/32	2 Sides	2 oz.	-----	16.8	-----	-----
23	3/32	2 Sides	2 oz.	-----	17.0	-----	-----
24	3/32	2 Sides	2 oz.	-----	16.0	-----	-----
25	3/32	2 Sides	2 oz.	-----	16.0	-----	-----
26	3/32	2 Sides	2 oz.	-----	16.8	-----	-----
27	3/32	2 Sides	2 oz.	-----	-----	-----	-----
28	3/32	2 Sides	2 oz.	-----	17.0	-----	-----
29	3/32	2 Sides	2 oz.	-----	16.8	-----	-----
30	3/32	2 Sides	2 oz.	-----	16.0	-----	-----
31	3/32	2 Sides	2 oz.	-----	16.4	-----	-----
32	3/32	2 Sides	2 oz.	-----	16.4	-----	-----
Average Peel Strength Value					16.4		

TABLE LXXXII

PEEL STRENGTH OF MANUFACTURER B (3/32 INCH THICKNESS)

Paper Base Epoxy Laminate

Specimen Number	Composite Material Thickness (Inch)	Copper Clad	Copper Foil Weight (Ounces)	After Solder Dip (Lbs/Inch Width)	After Temperature Cycling (Lbs/Inch Width)	After Elevated Temperature (Lbs/Inch Width)	Condition A (Lbs/Inch Width)
1	3/32	2 Sides	1 oz.	9.5	10.0	9.0	12.0
2	3/32	2 Sides	1 oz.	10.0	11.0	10.0	11.0
3	3/32	2 Sides	1 oz.	9.5	11.0	11.0	10.0
4	3/32	2 Sides	1 oz.	11.0	10.0	10.0	11.0
5	3/32	2 Sides	1 oz.	10.0	10.0	10.0	11.0
6	3/32	2 Sides	1 oz.	10.0	10.0	9.5	11.0
7	3/32	2 Sides	1 oz.	11.0	10.0	10.5	11.0
8	3/32	2 Sides	1 oz.	11.0	9.5	9.0	12.0
9	3/32	2 Sides	1 oz.	10.0	10.0	10.0	12.0
10	3/32	2 Sides	1 oz.	9.0	9.5	9.0	10.0
11	3/32	2 Sides	1 oz.	9.0	11.0	10.0	11.0
12	3/32	2 Sides	1 oz.	10.0	10.0	11.0	11.0
13	3/32	2 Sides	1 oz.	10.0	10.0	9.0	11.0
14	3/32	2 Sides	1 oz.	9.5	9.0	10.0	11.0
15	3/32	2 Sides	1 oz.	10.0	9.0	10.0	11.0
16	3/32	2 Sides	1 oz.	10.0	10.0	10.0	11.0
Average Peel Strength Values				10.0	10.0	9.9	12.1
17	3/32	2 Sides	2 oz.	-----	14.0	-----	-----
18	3/32	2 Sides	2 oz.	-----	14.0	-----	-----
19	3/32	2 Sides	2 oz.	-----	14.0	-----	-----
20	3/32	2 Sides	2.oz.	-----	13.5	-----	-----
21	3/32	2 Sides	2 oz.	-----	13.0	-----	-----
22	3/32	2 Sides	2 oz.	-----	14.0	-----	-----
23	3/32	2 Sides	2 oz.	-----	14.0	-----	-----
24	3/32	2 Sides	2 oz.	-----	14.0	-----	-----
25	3/32	2 Sides	2 oz.	-----	14.0	-----	-----
26	3/32	2 Sides	2 oz.	-----	14.0	-----	-----
27	3/32	2 Sides	2 oz.	-----	14.0	-----	-----
28	3/32	2 Sides	2 oz.	-----	14.0	-----	-----
29	3/32	2 Sides	2 oz.	-----	14.0	-----	-----
30	3/32	2 Sides	2 oz.	-----	13.0	-----	-----
31	3/32	2 Sides	2 oz.	-----	14.0	-----	-----
32	3/32	2 Sides	2 oz.	-----	13.0	-----	-----
Average Peel Strength Value					13.8		

TABLE LXXXIII

PEEL STRENGTH OF MANUFACTURER D (3/32 INCH THICKNESS)

Paper Base Epoxy Laminate

Specimen Number	Composite Material Thickness (Inch)	Copper Clad	Copper Foil Weight (Ounces)	After Solder Dip (Lbs/Inch Width)	After Temperature Cycling (Lbs/Inch Width)	After Elevated Temperature (Lbs/Inch Width)	Condition A (Lbs Inch Width)
1	3/32	2 Sides	1 oz.	9.0	9.0	10.0	11.0
2	3/32	2 Sides	1 oz.	9.0	10.0	9.0	10.0
3	3/32	2 Sides	1 oz.	10.0	10.0	9.5	10.0
4	3/32	2 Sides	1 oz.	9.5	9.0	8.5	9.0
5	3/32	2 Sides	1 oz.	8.5	10.0	10.0	8.5
6	3/32	2 Sides	1 oz.	9.0	10.0	9.0	9.5
7	3/32	2 Sides	1 oz.	10.0	10.0	9.0	10.0
8	3/32	2 Sides	1 oz.	8.5	9.0	9.0	9.0
9	3/32	2 Sides	1 oz.	10.0	9.0	10.0	9.0
10	3/32	2 Sides	1 oz.	9.0	9.0	9.0	10.0
11	3/32	2 Sides	1 oz.	9.5	10.0	9.0	9.0
12	3/32	2 Sides	1 oz.	9.0	10.0	9.0	9.0
13	3/32	2 Sides	1 oz.	10.0	8.5	10.0	10.0
14	3/32	2 Sides	1 oz.	9.5	9.0	9.0	8.5
15	3/32	2 Sides	1 oz.	9.5	9.0	10.0	9.0
16	3/32	2 Sides	1 oz.	9.5	9.0	10.0	9.0
Average Peel Strength Values				9.3	9.4	9.4	9.4
17	3/32	2 Sides	2 oz.	12.0	13.0	10.8	12.0
18	3/32	2 Sides	2 oz.	12.0	12.0	11.0	12.0
19	3/32	2 Sides	2 oz.	12.2	13.0	11.6	12.0
20	3/32	2 Sides	2 oz.	12.2	12.0	11.6	12.4
21	3/32	2 Sides	2 oz.	12.6	12.0	11.6	12.8
22	3/32	2 Sides	2 oz.	12.2	12.0	11.6	12.0
23	3/32	2 Sides	2 oz.	11.2	13.0	12.0	11.2
24	3/32	2 Sides	2 oz.	11.6	12.0	10.8	11.6
25	3/32	2 Sides	2 oz.	11.4	11.5	10.8	11.6
26	3/32	2 Sides	2 oz.	12.0	13.0	11.6	12.4
27	3/32	2 Sides	2 oz.	12.0	12.0	10.8	12.0
28	3/32	2 Sides	2 oz.	12.0	13.0	10.5	12.0
29	3/32	2 Sides	2 oz.	11.6	10.5	12.0	11.6
30	3/32	2 Sides	2 oz.	12.6	14.0	11.6	12.8
31	3/32	2 Sides	2 oz.	12.0	12.0	12.4	12.0
32	3/32	2 Sides	2 oz.	12.0	12.0	11.6	12.0
Average Peel Strength Values				11.9	12.3	11.3	12.6

TABLE LXXXIV

PEEL STRENGTH OF MANUFACTURER A (1/8 INCH THICKNESS)

Paper Base Epoxy Laminate

Specimen Number	Composite Material Thickness (Inch)	Copper Clad	Copper Foil Weight (Ounces)	After Solder Dip (Lbs/Inch Width)	After Temperature Cycling (Lbs/Inch Width)	After Elevated Temperature (Lbs/Inch Width)	Condition A (Lbs/Inch Width)
1	1/8	1 Side	1 oz.	10.0	11.0	10.5	11.0
2	1/8	1 Side	1 oz.	9.5	11.0	10.5	11.0
3	1/8	1 Side	1 oz.	9.0	11.0	10.5	11.0
4	1/8	1 Side	1 oz.	8.5	10.5	10.5	11.5
5	1/8	1 Side	1 oz.	10.0	11.0	10.0	11.5
6	1/8	1 Side	1 oz.	9.0	11.0	10.5	11.0
7	1/8	1 Side	1 oz.	9.5	11.0	10.5	11.0
8	1/8	1 Side	1 oz.	9.5	10.5	10.5	11.5
Average Peel Strength Values				9.4	10.9	10.5	11.3
9	1/8	1 Side	2 oz.	14.0	14.5	14.0	16.0
10	1/8	1 Side	2 oz.	15.0	14.0	13.0	15.0
11	1/8	1 Side	2 oz.	14.0	13.5	15.0	17.0
12	1/8	1 Side	2 oz.	14.0	14.5	15.5	16.5
13	1/8	1 Side	2 oz.	15.0	15.0	16.0	17.0
14	1/8	1 Side	2 oz.	15.0	14.0	15.0	16.0
15	1/8	1 Side	2 oz.	15.0	14.0	15.5	15.0
16	1/8	1 Side	2 oz.	14.0	14.0	14.0	16.0
Average Peel Strength Values				14.5	14.2	14.8	16.1

TABLE LXXXV

PEEL STRENGTH OF MANUFACTURER B (1/8 INCH THICKNESS)

Paper Base Epoxy Laminate

1	1/8	1 Side	1 oz.	9.5	10.5	9.0	10.5
2	1/8	1 Side	1 oz.	9.5	10.5	9.0	10.5
3	1/8	1 Side	1 oz.	9.5	10.0	9.5	10.5
4	1/8	1 Side	1 oz.	9.5	9.5	9.5	10.5
5	1/8	1 Side	1 oz.	9.0	10.0	9.0	10.5
6	1/8	1 Side	1 oz.	8.5	10.0	9.0	10.0
7	1/8	1 Side	1 oz.	8.5	10.0	9.0	10.5
8	1/8	1 Side	1 oz.	9.0	9.5	9.5	10.0
Average Peel Strength Values				8.1	10.0	9.2	10.4
9	1/8	1 Side	2 oz.	13.5	12.0	13.0	14.0
10	1/8	1 Side	2 oz.	12.0	12.5	14.0	14.0
11	1/8	1 Side	2 oz.	13.0	13.0	12.5	14.0
12	1/8	1 Side	2 oz.	12.0	12.0	13.0	13.5
13	1/8	1 Side	2 oz.	12.0	11.5	12.0	14.0
14	1/8	1 Side	2 oz.	12.0	11.0	12.0	14.5
15	1/8	1 Side	2 oz.	12.5	11.0	12.0	14.0
16	1/8	1 Side	2 oz.	13.0	12.0	12.5	14.0
Average Peel Strength Values				12.5	11.9	12.6	14.3

TABLE LXXXVI

PEEL STRENGTH OF MANUFACTURE D (1/8 INCH THICKNESS)

Paper Base Epoxy Laminate

Specimen Number	Composite Material Thickness (Inch)	Copper Clad	Copper Foil Weight (Ounces)	After Solder Dip (Lbs/Inch Width)	After Temperature Cycling (Lbs/Inch Width)	After Elevated Temperature (Lbs/Inch Width)	Condition A (Lbs/Inch Width)
1	1/8	1 Side	1 oz.	9.5	10.5	9.0	10.0
2	1/8	1 Side	1 oz.	8.5	10.0	9.0	10.0
3	1/8	1 Side	1 oz.	10.0	10.0	9.5	10.5
4	1/8	1 Side	1 oz.	10.0	9.5	8.5	10.0
5	1/8	1 Side	1 oz.	9.5	10.0	9.0	10.5
6	1/8	1 Side	1 oz.	9.0	10.0	9.0	10.0
7	1/8	1 Side	1 oz.	9.5	10.5	9.5	10.0
8	1/8	1 Side	1 oz.	8.5	9.5	9.5	10.5
Average Peel Strength Values				9.3	10.0	9.1	10.2
9	1/8	1 Side	2 oz.	11.0	12.0	12.5	13.0
10	1/8	1 Side	2 oz.	10.5	12.0	12.0	13.0
11	1/8	1 Side	2 oz.	9.5	12.5	13.0	13.5
12	1/8	1 Side	2 oz.	9.5	12.0	12.0	13.0
13	1/8	1 Side	2 oz.	10.5	13.0	12.5	14.0
14	1/8	1 Side	2 oz.	11.0	13.0	12.5	13.5
15	1/8	1 Side	2 oz.	11.0	12.5	13.0	13.0
16	1/8	1 Side	2 oz.	10.5	13.0	12.5	14.0
Average Peel Strength Values				10.6	12.5	12.5	13.4

TABLE LXXXVII

PEEL STRENGTH OF MANUFACTURER A (1/4 INCH THICKNESS)

Paper Base Epoxy Laminate

1	1/4	1 Side	1 oz.	12.5	12.5	12.5	12.5
2	1/4	1 Side	1 oz.	12.5	12.5	12.0	12.5
3	1/4	1 Side	1 oz.	12.0	13.0	12.5	12.0
4	1/4	1 Side	1 oz.	12.0	12.5	12.0	12.0
5	1/4	1 Side	1 oz.	12.5	13.0	13.0	12.5
6	1/4	1 Side	1 oz.	12.5	12.5	12.0	13.0
7	1/4	1 Side	1 oz.	13.5	13.0	12.5	13.5
8	1/4	1 Side	1 oz.	13.0	13.0	12.5	12.5
Average Peel Strength				12.6	12.8	12.4	12.5
9	1/4	1 Side	2 oz.	14.0	13.5	14.0	15.5
10	1/4	1 Side	2 oz.	14.5	13.0	15.0	14.5
11	1/4	1 Side	2 oz.	15.0	12.5	14.0	15.0
12	1/4	1 Side	2 oz.	13.5	13.0	14.0	16.5
13	1/4	1 Side	2 oz.	14.5	13.0	15.0	15.5
14	1/4	1 Side	2 oz.	13.0	13.0	14.0	15.0
15	1/4	1 Side	2 oz.	14.0	14.0	15.0	16.0
16	1/4	1 Side	2 oz.	14.5	13.5	15.0	15.0
Average Peel Strength Values				14.1	13.2	14.5	15.4

TABLE LXXXVIII

PEEL STRENGTH OF MANUFACTURER B (1/4 INCH THICKNESS)

Paper Base Epoxy Laminate

Specimen Number	Composite Material Thickness (Inch)	Copper Clad	Copper Foil Weight (Ounces)	After Solder Dip (Lbs/Inch Width)	After Temperature Cycling (Lbs/Inch Width)	After Elevated Temperature (Lbs/Inch Width)	Condition A (Lbs/Inch Width)
1	1/4	1 Side	1 oz.	9.0	9.5	8.5	10.0
2	1/4	1 Side	1 oz.	9.5	10.5	8.5	10.0
3	1/4	1 Side	1 oz.	10.0	9.5	8.0	10.0
4	1/4	1 Side	1 oz.	9.5	9.5	8.5	10.0
5	1/4	1 Side	1 oz.	9.5	9.5	7.0	10.0
6	1/4	1 Side	1 oz.	9.0	9.5	8.0	10.0
7	1/4	1 Side	1 oz.	8.5	9.5	8.5	10.0
8	1/4	1 Side	1 oz.	8.5	9.5	9.0	10.0
Average Peel Strength Values				9.1	9.6	8.6	10.0
9	1/4	1 Side	2 oz.	13.5	14.0	14.0	14.0
10	1/4	1 Side	2 oz.	12.0	14.0	13.0	14.0
11	1/4	1 Side	2 oz.	12.5	13.0	13.0	14.0
12	1/4	1 Side	2 oz.	13.5	12.5	14.0	15.5
13	1/4	1 Side	2 oz.	13.0	13.0	13.0	14.0
14	1/4	1 Side	2 oz.	13.5	14.0	14.0	14.0
15	1/4	1 Side	2 oz.	12.0	13.0	13.0	14.0
16	1/4	1 Side	2 oz.	13.0	13.5	13.0	14.5
Average Peel Strength Values				12.9	13.4	13.4	14.3

TABLE LXXXIX

PEEL STRENGTH OF MANUFACTURER D (1/4 INCH THICKNESS)

Paper Base Epoxy Laminate

1	1/4	1 Side	1 oz.	9.0	9.5	9.0	10.5
2	1/4	1 Side	1 oz.	9.5	13.0	9.0	10.5
3	1/4	1 Side	1 oz.	8.0	9.5	9.5	10.5
4	1/4	1 Side	1 oz.	9.5	11.0	9.5	10.5
5	1/4	1 Side	1 oz.	10.0	10.5	9.5	11.0
6	1/4	1 Side	1 oz.	9.0	10.0	10.0	10.5
7	1/4	1 Side	1 oz.	10.0	10.0	9.5	10.5
8	1/4	1 Side	1 oz.	10.0	10.0	9.5	10.5
Average Peel Strength Values				9.4	10.4	9.4	10.5
9	1/4	1 Side	2 oz.	12.0	12.0	13.0	13.5
10	1/4	1 Side	2 oz.	11.5	11.0	12.0	14.0
11	1/4	1 Side	2 oz.	12.0	12.0	12.0	14.0
12	1/4	1 Side	2 oz.	11.5	12.0	12.0	13.5
13	1/4	1 Side	2 oz.	12.0	12.0	12.0	13.0
14	1/4	1 Side	2 oz.	11.0	12.0	13.0	13.0
15	1/4	1 Side	2 oz.	11.0	12.0	13.0	13.0
16	1/4	1 Side	2 oz.	12.0	11.0	12.0	13.0
Average Peel Strength Values				11.6	11.8	12.4	13.4

TABLE XC

VOLUME RESISTIVITY AND SURFACE RESISTANCE TEST RESULTS OF MANUFACTURER A (1/16 AND 3/32 INCH THICKNESS

Paper Base Epoxy Laminate

Specimen Number	Copper Clad	Copper Foil Weight (Ounces)	Composite Material Thickness (Inch)	Volume Resistivity R_V (Megohm-Centimeters)	Surface Resistance R_S (Megohms)
1	Two Sides	1 oz.	1/16	1.4×10^8	5×10^5
2	Two Sides	1 oz.	1/16	4.3×10^8	5×10^5
3	Two Sides	1 oz.	1/16	1.29×10^8	5×10^5
4	Two Sides	1 oz.	1/16	2.16×10^8	2×10^5
5	Two Sides	1 oz.	1/16	1.29×10^8	4×10^5
6	Two Sides	1 oz.	1/16	3.23×10^8	3.5×10^5
7	Two Sides	1 oz.	1/16	2.48×10^8	5×10^5
8	Two Sides	1 oz.	1/16	2.69×10^8	8×10^5
9	Two Sides	1 oz.	1/16	1.85×10^8	7×10^5
10	Two Sides	1 oz.	1/16	4.97×10^8	7×10^5
11	Two Sides	1 oz.	1/16	4.97×10^8	7×10^5
12	Two Sides	1 oz.	1/16	0.99×10^8	7×10^5
13	Two Sides	1 oz.	1/16	0.61×10^8	8×10^5
			Average Value	2.49×10^8	5.70×10^5
14	Two Sides	2 oz.	3/32	6.15×10^8	2.0×10^5
15	Two Sides	2 oz.	3/32	6.50×10^8	1.6×10^5
16	Two Sides	2 oz.	3/32	7.17×10^8	0.8×10^5
17	Two Sides	2 oz.	3/32	9.47×10^8	1.3×10^5
18	Two Sides	2 oz.	3/32	7.17×10^8	2.0×10^5
19	Two Sides	2 oz.	3/32	8.60×10^8	2.0×10^5
20	Two Sides	2 oz.	3/32	7.81×10^8	0.53×10^5
21	Two Sides	2 oz.	3/32	7.27×10^8	0.72×10^5
22	Two Sides	2 oz.	3/32	8.10×10^8	1.8×10^5
23	Two Sides	2 oz.	3/32	10.70×10^8	3.0×10^5
24	Two Sides	2 oz.	3/32	9.40×10^8	0.8×10^5
25	Two Sides	2 oz.	3/32	8.00×10^8	2.0×10^5
26	Two Sides	2 oz.	3/32	6.50×10^8	2.0×10^5
27	Two Sides	2 oz.	3/32	7.00×10^8	2.0×10^5
28	Two Sides	2 oz.	3/32	8.60×10^8	1.0×10^5
29	Two Sides	2 oz.	3/32	9.47×10^8	5.0×10^5
			Average Value	8.00×10^8	1.83×10^5

TABLE XCI

VOLUME RESISTIVITY AND SURFACE RESISTANCE TEST RESULTS OF MANUFACTURER B (1/16 AND 3/32 INCH THICKNESS)

Paper Base Epoxy Laminate

Specimen Number	Copper Clad	Copper Foil Weight (Ounces)	Composite Material Thickness (Inch)	Volume Resistivity R_V (Megohm-Centimeters)	Surface Resistance R_S (Megohms)
1	Two Sides	1 oz.	1/16	3.40×10^8	20.4×10^5
2	Two Sides	1 oz.	1/16	5.38×10^8	27.0×10^5
3	Two Sides	1 oz.	1/16	5.30×10^8	22.2×10^5
4	Two Sides	1 oz.	1/16	5.86×10^8	28.6×10^5
5	Two Sides	1 oz.	1/16	5.63×10^8	20.0×10^5
6	Two Sides	1 oz.	1/16	6.47×10^8	22.8×10^5
7	Two Sides	1 oz.	1/16	4.98×10^8	33.4×10^5
8	Two Sides	1 oz.	1/16	4.78×10^8	29.4×10^5
9	Two Sides	1 oz.	1/16	5.40×10^8	18.6×10^5
10	Two Sides	1 oz.	1/16	11.95×10^8	20.0×10^5
11	Two Sides	1 oz.	1/16	7.18×10^8	19.2×10^5
12	Two Sides	1 oz.	1/16	4.98×10^8	16.2×10^5
13	Two Sides	1 oz.	1/16	5.86×10^8	23.3×10^5
14	Two Sides	1 oz.	1/16	5.38×10^8	22.8×10^5
15	Two Sides	1 oz.	1/16	5.38×10^8	24.2×10^5
16	Two Sides	1 oz.	1/16	7.18×10^8	21.8×10^5
			Average Value	5.95×10^8	21.6×10^5
17	Two Sides	2 oz.	3/32	5.37×10^8	17.8×10^5
18	Two Sides	2 oz.	3/32	7.17×10^8	13.9×10^5
19	Two Sides	2 oz.	3/32	7.81×10^8	21.7×10^5
20	Two Sides	2 oz.	3/32	6.15×10^8	12.2×10^5
21	Two Sides	2 oz.	3/32	7.17×10^8	21.8×10^5
22	Two Sides	2 oz.	3/32	6.72×10^8	25.6×10^5
23	Two Sides	2 oz.	3/32	6.95×10^8	20.0×10^5
24	Two Sides	2 oz.	3/32	6.53×10^8	14.5×10^5
25	Two Sides	2 oz.	3/32	35.80×10^8	33.4×10^5
26	Two Sides	2 oz.	3/32	86.00×10^8	56.8×10^5
27	Two Sides	2 oz.	3/32	6.72×10^8	12.5×10^5
28	Two Sides	2 oz.	3/32	5.74×10^8	16.7×10^5
29	Two Sides	2 oz.	3/32	97.50×10^8	20.4×10^5
30	Two Sides	2 oz.	3/32	6.15×10^8	16.7×10^5
31	Two Sides	2 oz.	3/32	6.33×10^8	55.8×10^5
32	Two Sides	2 oz.	3/32	6.63×10^8	13.2×10^5
			Average Value	6.57×10^8	18.6×10^5

TABLE XCII

VOLUME RESISTIVITY AND SURFACE RESISTANCE TEST RESULTS OF MANUFACTURER D (1/16 AND 3/32 INCH THICKNESS)

Paper Base Epoxy Laminate

Specimen Number	Copper Clad	Copper Foil Weight (Ounces)	Composite Material Thickness (Inch)	Volume Resistivity Rv (Megohm-Centimeters)	Surface Resistance Rs (Megohms)
1	Two Sides	1 oz.	1/16	1.030×10^8	28.6×10^5
2	Two Sides	1 oz.	1/16	0.996×10^8	25.0×10^5
3	Two Sides	1 oz.	1/16	0.938×10^8	27.8×10^5
4	Two Sides	1 oz.	1/16	0.770×10^8	17.25×10^5
5	Two Sides	1 oz.	1/16	0.938×10^8	13.15×10^5
6	Two Sides	1 oz.	1/16	1.019×10^8	22.70×10^5
7	Two Sides	1 oz.	1/16	0.702×10^8	22.70×10^5
8	Two Sides	1 oz.	1/16	0.925×10^8	50.00×10^5
9	Two Sides	1 oz.	1/16	0.572×10^8	13.15×10^5
10	Two Sides	1 oz.	1/16	0.874×10^8	21.30×10^5
11	Two Sides	1 oz.	1/16	1.010×10^8	18.85×10^5
12	Two Sides	1 oz.	1/16	0.862×10^8	91.0×10^5
13	Two Sides	1 oz.	1/16	1.078×10^8	15.62×10^5
14	Two Sides	1 oz.	1/16	0.996×10^8	41.70×10^5
15	Two Sides	1 oz.	1/16	0.828×10^8	55.50×10^5
16	Two Sides	1 oz.	1/16	1.028×10^8	46.70×10^5
			Average Value	0.910×10^8	28.0×10^5
17	Two Sides	2 oz.	3/32	1.130×10^8	51.5×10^5
18	Two Sides	2 oz.	3/32	1.148×10^8	42.7×10^5
19	Two Sides	2 oz.	3/32	1.075×10^8	48.0×10^5
20	Two Sides	2 oz.	3/32	0.730×10^8	40.3×10^5
21	Two Sides	2 oz.	3/32	1.195×10^8	42.4×10^5
22	Two Sides	2 oz.	3/32	0.796×10^8	27.4×10^5
23	Two Sides	2 oz.	3/32	0.606×10^8	34.95×10^5
24	Two Sides	2 oz.	3/32	1.025×10^8	87.71×10^5
25	Two Sides	2 oz.	3/32	0.488×10^8	61.00×10^5
26	Two Sides	2 oz.	3/32	1.025×10^8	43.50×10^5
27	Two Sides	2 oz.	3/32	0.895×10^8	91.0×10^5
28	Two Sides	2 oz.	3/32	0.934×10^8	86.3×10^5
29	Two Sides	2 oz.	3/32	1.048×10^8	80.7×10^5
30	Two Sides	2 oz.	3/32	1.076×10^8	74.7×10^5
31	Two Sides	2 oz.	3/32	0.642×10^8	53.2×10^5
32	Two Sides	2 oz.	3/32	0.812×10^8	44.7×10^5
			Average Value	0.915×10^8	35.5×10^5

TABLE XCIII

VOLUME RESISTIVITY AND SURFACE RESISTANCE TEST RESULTS OF MANUFACTURER A AND B (1/8 INCH THICKNESS)

Paper Base Epoxy Laminate

Specimen Number	Copper Clad	Copper Foil Weight (Ounces)	Composite Material Thickness (Inch)	Volume Resistivity R_V (Megohm-Centimeters)	Surface Resistance R_S (Megohms)
1	Two Sides	1 oz.	1/8	1.30×10^{8}	4.1×10^{5}
2	Two Sides	1 oz.	1/8	1.35×10^{8}	2.5×10^{5}
3	Two Sides	1 oz.	1/8	2.45×10^{8}	3.4×10^{5}
4	Two Sides	1 oz.	1/8	3.40×10^{8}	6.3×10^{5}
5	Two Sides	1 oz.	1/8	4.00×10^{8}	8.4×10^{5}
6	Two Sides	1 oz.	1/8	3.24×10^{8}	10.0×10^{5}
7	Two Sides	1 oz.	1/8	4.65×10^{8}	6.0×10^{5}
8	Two Sides	1 oz.	1/8	1.75×10^{8}	5.0×10^{5}
9	Two Sides	1 oz.	1/8	2.50×10^{6}	6.3×10^{5}
10	Two Sides	1 oz.	1/8	2.45×10^{8}	4.7×10^{5}
11	Two Sides	1 oz.	1/8	3.08×10^{8}	7.3×10^{5}
12	Two Sides	1 oz.	1/8	2.75×10^{8}	10.4×10^{5}
13	Two Sides	1 oz.	1/8	1.85×10^{8}	7.0×10^{5}
14	Two Sides	1 oz.	1/8	3.46×10^{8}	6.5×10^{5}
15	Two Sides	1 oz.	1/8	1.65×10^{8}	9.0×10^{5}
16	Two Sides	1 oz.	1/8	2.75×10^{8}	8.8×10^{5}
Average Value for Manufacturer A				2.42×10^{8}	5.98×10^{5}
17	Two Sides	1 oz.	1/8	4.58×10^{8}	100×10^{5}
18	Two Sides	1 oz.	1/8	5.08×10^{8}	26.9×10^{5}
19	Two Sides	1 oz.	1/8	6.40×10^{8}	15.6×10^{5}
20	Two Sides	1 oz.	1/8	5.01×10^{8}	40.6×10^{5}
21	Two Sides	1 oz.	1/8	6.15×10^{8}	43.8×10^{5}
22	Two Sides	1 oz.	1/8	6.67×10^{8}	8.47×10^{5}
23	Two Sides	1 oz.	1/8	6.16×10^{8}	49.0×10^{5}
24	Two Sides	1 oz.	1/8	8.43×10^{8}	39.1×10^{5}
25	Two Sides	1 oz.	1/8	6.96×10^{8}	45.5×10^{5}
26	Two Sides	1 oz.	1/8	4.93×10^{8}	46.7×10^{5}
27	Two Sides	1 oz.	1/8	6.96×10^{8}	51.5×10^{5}
28	Two Sides	1 oz.	1/8	6.67×10^{8}	42.4×10^{5}
29	Two Sides	1 oz.	1/8	6.67×10^{8}	25.9×10^{5}
30	Two Sides	1 oz.	1/8	5.34×10^{8}	53.2×10^{5}
31	Two Sides	1 oz.	1/8	8.00×10^{8}	69.5×10^{5}
32	Two Sides	1 oz.	1/8	6.40×10^{8}	19.5×10^{5}
Average Value for Manufacturer B				6.28×10^{8}	35.0×10^{5}

TABLE XCIV

VOLUME RESISTIVITY AND SURFACE RESISTANCE TEST RESULTS OF MANUFACTURER D (1/8 INCH THICKNESS)

Paper Base Epoxy Laminate

Specimen Number	Copper	Copper Foil Weight (Ounces)	Composite Material Thickness (Inch)	Volume Resistivity Rv (Megohm-Centimeters)	Surface Resistance Rs (Megohms)
1	Two Sides	1 oz.	1/8	1.040×10^{8}	32.41×10^{5}
2	Two Sides	1 oz.	1/8	0.828×10^{8}	17.62×10^{5}
3	Two Sides	1 oz.	1/8	0.928×10^{8}	33.14×10^{5}
4	Two Sides	1 oz.	1/8	0.725×10^{8}	18.23×10^{5}
5	Two Sides	1 oz.	1/8	1.000×10^{8}	24.78×10^{5}
6	Two Sides	1 oz.	1/8	1.400×10^{8}	22.34×10^{5}
7	Two Sides	1 oz.	1/8	1.768×10^{8}	29.70×10^{5}
8	Two Sides	1 oz.	1/8	0.973×10^{8}	31.60×10^{5}
9	Two Sides	1 oz.	1/8	0.974×10^{8}	27.27×10^{5}
10	Two Sides	1 oz.	1/8	1.275×10^{8}	38.44×10^{5}
11	Two Sides	1 oz.	1/8	1.250×10^{8}	33.62×10^{5}
12	Two Sides	1 oz.	1/8	1.346×10^{8}	35.40×10^{5}
13	Two Sides	1 oz.	1/8	1.234×10^{8}	33.15×10^{5}
14	Two Sides	1 oz.	1/8	1.040×10^{8}	34.00×10^{5}
15	Two Sides	1 oz.	1/8	0.986×10^{8}	29.40×10^{5}
16	Two Sides	1 oz.	1/8	1.740×10^{8}	28.75×10^{5}
			Average Value	1.160×10^{8}	29.30×10^{5}

TABLE XCV

WATER ABSORPTION TEST RESULTS OF MANUFACTURER A

Paper Base Epoxy Laminate

Specimen Number	Composite Material Thickness (Inches)	Copper Clad	Copper Foil Weight (Ounces)	Manufacturer	& Absorption
1	1/16	Double	1 oz.	A	0.49
2	1/16	Double	1 oz.	A	0.46
3	1/16	Double	1 oz.	A	0.78
4	1/16	Double	1 oz.	A	0.44
5	1/16	Double	1 oz.	A	0.51
6	1/16	Double	1 oz.	A	0.52
7	1/16	Double	1 oz.	A	0.49
8	1/16	Double	1 oz.	A	0.54
9	1/16	Double	1 oz.	A	0.24
10	1/16	Double	1 oz.	A	0.45
11	1/16	Double	1 oz.	A	0.52
12	1/16	Double	1 oz.	A	0.52
13	1/16	Double	1 oz.	A	0.47
14	1/16	Double	1 oz.	A	0.52
15	1/16	Double	1 oz.	A	0.46
16	1/16	Double	1 oz.	A	0.49
				Average Value	0.49
17	3/32	Double	2 oz.	A	0.38
18	3/32	Double	2 oz.	A	0.39
19	3/32	Double	2 oz.	A	0.37
20	3/32	Double	2 oz.	A	0.31
21	3/32	Double	2 oz.	A	0.45
22	3/32	Double	2 oz.	A	0.27
23	3/32	Double	2 oz.	A	0.31
24	3/32	Double	2 oz.	A	0.40
25	3/32	Double	2 oz.	A	0.32
26	3/32	Double	2 oz.	A	0.33
27	3/32	Double	2 oz.	A	0.32
28	3/32	Double	2 oz.	A	0.31
29	3/32	Double	2 oz.	A	0.34
30	3/32	Double	2 oz.	A	0.39
31	3/32	Double	2 oz.	A	0.36
32	3/32	Double	2 oz.	A	0.34
				Average Value	0.35
33	1/8	Single	1 oz.	A	0.35
34	1/8	Single	1 oz.	A	0.34
35	1/8	Single	1 oz.	A	0.30
36	1/8	Single	1 oz.	A	0.37
37	1/8	Single	1 oz.	A	0.43
38	1/8	Single	1 oz.	A	0.44

TABLE XCV (CONT)

WATER ABSORPTION TEST RESULTS OF MANUFACTURER A

Paper Base Epoxy Laminate

Specimen Number	Composite Material Thickness (Inches)	Copper Clad	Copper Foil Weight (Ounces)	Manufacturer	& Absorption
39	1/8	Single	1 oz.	A	0.46
40	1/8	Single	1 oz.	A	0.30
41	1/8	Single	1 oz.	A	0.25
42	1/8	Single	1 oz.	A	0.30
43	1/8	Single	1 oz.	A	0.28
44	1/8	Single	1 oz.	A	0.34
45	1/8	Single	1 oz.	A	0.32
46	1/8	Single	1 oz.	A	0.40
47	1/8	Single	1 oz.	A	0.36
48	1/8	Single	1 oz.	A	0.33
				Average Value	0.35

TABLE XCVI

WATER ABSORPTION TEST RESULTS OF MANUFACTURER B

Paper Base Epoxy Laminate

Specimen Number	Composite Material Thickness (Inches)	Copper Clad	Copper Foil Weight (Ounces)	Manufacturer	& Absorption
1	1/16	Double	1 oz.	B	0.42
2	1/16	Double	1 oz.	B	0.42
3	1/16	Double	1 oz.	B	0.47
4	1/16	Double	1 oz.	B	0.45
5	1/16	Double	1 oz.	B	0.44
6	1/16	Double	1 oz.	B	0.42
7	1/16	Double	1 oz.	B	0.46
8	1/16	Double	1 oz.	B	0.38
9	1/16	Double	1 oz.	B	0.47
10	1/16	Double	1 oz.	B	0.44
11	1/16	Double	1 oz.	B	0.40
12	1/16	Double	1 oz.	B	0.41
13	1/16	Double	1 oz.	B	0.45
14	1/16	Double	1 oz.	B	0.42
15	1/16	Double	1 oz.	B	0.45
16	1/16	Double	1 oz.	B	0.52
				Average Value	0.44
17	3/32	Double	2 oz.	B	0.29
18	3/32	Double	2 oz.	B	0.36
19	3/32	Double	2 oz.	B	0.37
20	3/32	Double	2 oz.	B	0.27
21	3/32	Double	2 oz.	B	0.28
22	3/32	Double	2 oz.	B	0.26
23	3/32	Double	2 oz.	B	0.29
24	3/32	Double	2 oz.	B	0.28
25	3/32	Double	2 oz.	B	0.26
26	3/32	Double	2 oz.	B	0.30
27	3/32	Double	2 oz.	B	0.35
28	3/32	Double	2 oz.	B	0.24
29	3/32	Double	2 oz.	B	0.27
30	3/32	Double	2 oz.	B	0.25
31	3/32	Double	2 oz.	B	0.27
32	3/32	Double	2 oz.	B	0.26
				Average Value	0.29
33	1/8	Single	1 oz.	B	0.32
34	1/8	Single	1 oz.	B	0.35
35	1/8	Single	1 oz.	B	0.27
36	1/8	Single	1 oz.	B	0.28
37	1/8	Single	1 oz.	B	0.32
38	1/8	Single	1 oz.	B	0.23

TABLE XCVI (CONT)

WATER ABSORPTION TEST RESULTS OF MANUFACTURER B

Paper Base Epoxy Laminate

Specimen Number	Composite Material Thickness (Inches)	Copper Clad	Copper Foil Weight (Ounces)	Manufacturer	& Absorption
39	1/8	Single	1 oz.	B	0.34
40	1/8	Single	1 oz.	B	0.26
41	1/8	Single	1 oz.	B	0.22
42	1/8	Single	1 oz.	B	0.29
43	1/8	Single	1 oz.	B	0.33
44	1/8	Single	1 oz.	B	0.26
45	1/8	Single	1 oz.	B	0.29
46	1/8	Single	1 oz.	B	0.24
47	1/8	Single	1 oz.	B	0.33
48	1/8	Single	1 oz.	B	0.36
				Average Value	0.29

TABLE XCVII

WATER ABSORPTION TEST RESULTS OF MANUFACTURER D (1/16 AND 3/32 THICKNESS)

Paper Base Epoxy Laminate

Specimen Number	Composite Material Thickness (Inch)	Copper Clad	Copper Foil Weight (Ounces)	Manufacturer	% Absorption
1	1/16	Double	1 oz.	D	0.44
2	1/16	Double	1 oz.	D	0.45
3	1/16	Double	1 oz.	D	0.54
4	1/16	Double	1 oz.	D	0.56
5	1/16	Double	1 oz.	D	0.45
6	1/16	Double	1 oz.	D	0.42
7	1/16	Double	1 oz.	D	0.43
8	1/16	Double	1 oz.	D	
9	1/16	Double	1 oz.	D	* 0.43
10	1/16	Double	1 oz.	D	0.44
11	1/16	Double	1 oz.	D	0.39
12	1/16	Double	1 oz.	D	0.45
13	1/16	Double	1 oz.	D	0.41
14	1/16	Double	1 oz.	D	0.36
15	1/16	Double	1 oz.	D	0.41
16	1/16	Double	1 oz.	D	0.37
				Average Value	0.44
17	3/32	Double	2 oz.	D	0.21
18	3/32	Double	2 oz.	D	0.17
19	3/32	Double	2 oz.	D	0.29
20	3/32	Double	2 oz.	D	0.22
21	3/32	Double	2 oz.	D	0.27
22	3/32	Double	2 oz.	D	0.25
23	3/32	Double	2 oz.	D	0.24
24	3/32	Double	2 oz.	D	0.26
25	3/32	Double	2 oz.	D	0.22
26	3/32	Double	2 oz.	D	0.30
27	3/32	Double	2 oz.	D	0.19
28	3/32	Double	2 oz.	D	
29	3/32	Double	2 oz.	D	0.25
30	3/32	Double	2 oz.	D	0.15
31	3/32	Double	2 oz.	D	0.30
32	3/32	Double	2 oz.	D	0.20
				Average Value	0.24

* SPECIMEN NOT TESTED BECAUSE OF BEING DAMAGED

TABLE XCVIII

WATER ABSORPTION TEST RESULTS OF MANUFACTURER D (1/8 INCH THICKNESS)

Paper Base Epoxy Laminate

Specimen Number	Composite Material Thickness (Inch)	Copper Clad	Copper Foil Weight (Ounces)	Manufacturer	% Absorption
1	1/8	Single	1 oz.	D	0.34
2	1/8	Single	1 oz.	D	0.39
3	1/8	Single	1 oz.	D	0.33
4	1/8	Single	1 oz.	D	0.25
5	1/8	Single	1 oz.	D	0.28
6	1/8	Single	1 oz.	D	0.36
7	1/8	Single	1 oz.	D	0.32
8	1/8	Single	1 oz.	D	0.34
9	1/8	Single	1 oz.	D	0.37
10	1/8	Single	1 oz.	D	0.33
11	1/8	Single	1 oz.	D	0.38
12	1/8	Single	1 oz.	D	0.34
13	1/8	Single	1 oz.	D	0.29
14	1/8	Single	1 oz.	D	0.27
15	1/8	Single	1 oz.	D	0.30
16	1/8	Single	1 oz.	D	0.33
				Average Value	0.32

TABLE XCIX

DIELECTRIC BREAKDOWN TEST RESULTS OF MANUFACTURER A

Paper-Base Epoxy Laminate

Specimen Number	Composite Material Thickness (Inch)	Copper Clad	Copper Foil Weight (Ounces)	Breakdown Voltage (Kilovolts)
1	1/32	Single	1 oz.	32.5
2	1/32	Single	1 oz.	37.5
3	1/32	Single	1 oz.	32.5
4	1/32	Single	1 oz.	32.5
5	1/32	Single	1 oz.	30.0
			Average Value	33.0
6	1/16	Double	1 oz.	45.0
7	1/16	Double	1 oz.	45.0
8	1/16	Double	1 oz.	40.0
9	1/16	Double	1 oz.	40.0
10	1/16	Double	1 oz.	45.0
			Average Value	43.0
11	3/32	Single	1 oz.	>55.0
12	3/32	Single	1 oz.	>55.0
13	3/32	Single	1 oz.	>55.0
14	3/32	Single	1 oz.	>55.0
15	3/32	Single	1 oz.	>55.0
			Average Value	>55.0
16	1/8	Single	1 oz.	55.0
17	1/8	Single	1 oz.	>55.0
18	1/8	Single	1 oz.	>55.0
19	1/8	Single	1 oz.	50.0
20	1/8	Single	1 oz.	>55.0
			Average Value	>54.0
21	1/4	Single	1 oz.	50.0
22	1/4	Single	1 oz.	>55.0
23	1/4	Single	1 oz.	50.0
24	1/4	Single	1 oz.	>55.0
25	1/4	Single	1 oz.	55.0
			Average Value	>53.0

Note: >indicates a value greater than that shown.

TABLE C

DIELECTRIC BREAKDOWN TEST RESULTS OF MANUFACTURER B

Paper Base Epoxy Laminate

Specimen Number	Composite Material Thickness (Inch)	Copper Clad	Copper Foil Weight (Ounces)	Breakdown Voltage (Kilovolts)
1	1/32	Single	1 oz.	>55.0
2	1/32	Single	1 oz.	>55.0
3	1/32	Single	1 oz.	>55.0
4	1/32	Single	1 oz.	>55.0
5	1/32	Single	1 oz.	>55.0
			Average Value	>55.0
6	1/16	Double	1 oz.	45.0
7	1/16	Double	1 oz.	55.0
8	1/16	Double	1 oz.	>55.0
9	1/16	Double	1 oz.	>55.0
10	1/16	Double	1 oz.	>55.0
			Average Value	>53.0
11	3/32	Single	1 oz.	>55.0
12	3/32	Single	1 oz.	>55.0
13	3/32	Single	1 oz.	>55.0
14	3/32	Single	1 oz.	55.0
15	3/32	Single	1 oz.	>55.0
			Average Value	>55.0
16	1/8	Single	1 oz.	>55.0
17	1/8	Single	1 oz.	>55.0
18	1/8	Single	1 oz.	>55.0
19	1/8	Single	1 oz.	>55.0
20	1/8	Single	1 oz.	>55.0
			Average Value	>55.0
21	1/4	Single	1 oz.	>55.0
22	1/4	Single	1 oz.	>55.0
23	1/4	Single	1 oz.	>55.0
24	1/4	Single	1 oz.	>55.0
25	1/4	Single	1 oz.	>55.0
			Average Value	>55.0

Note: >indicates a value greater than that shown.

TABLE CI

DIELECTRIC BREAKDOWN TEST RESULTS OF MANUFACTURER D

Paper Base Epoxy Laminate

Specimen Number	Composite Material Thickness (Inch)	Copper Clad	Copper Foil Weight (Ounces)	Breakdown Voltage (Kilovolts)
1	1/32	Single	1 oz.	>55.0
2	1/32	Single	1 oz.	>55.0
3	1/32	Single	1 oz.	>55.0
4	1/32	Single	1 oz.	>55.0
5	1/32	Single	1 oz.	>55.0
			Average Value	>55.0
6	1/16	Double	1 oz.	>55.0
7	1/16	Double	1 oz.	>55.0
8	1/16	Double	1 oz.	55.0
9	1/16	Double	1 oz.	55.0
10	1/16	Double	1 oz.	>55.0
			Average Value	>55.0
11	3/32	Single	1 oz.	>55.0
12	3/32	Single	1 oz.	>55.0
13	3/32	Single	1 oz.	>55.0
14	3/32	Single	1 oz.	>55.0
15	3/32	Single	1 oz.	>55.0
			Average Value	>55.0
16	1/8	Single	1 oz.	>55.0
17	1/8	Single	1 oz.	>55.0
18	1/8	Single	1 oz.	>55.0
19	1/8	Single	1 oz.	>55.0
20	1/8	Single	1 oz.	>55.0
			Average Value	>55.0
21	1/4	Single	1 oz.	>55.0
22	1/4	Single	1 oz.	>55.0
23	1/4	Single	1 oz.	>55.0
24	1/4	Single	1 oz.	>55.0
25	1/4	Single	1 oz.	>55.0
			Average Value	>55.0

Note: >indicates a value greater than that shown.

6.4.7 Dielectric Constant and Dissipation Factor

Tables CII and CIII show the test results of dielectric constant and dissipation factor for Vendors A, B and D.

6.4.8 Flexure Test

These tests were performed in accordance with MIL-P-13949B and reported in Tables CIV to CXVIII. The overall test results were consistent from one vendor to another. There was an average of 400 P.S.I. variation between lengthwise and crosswise flexure strength values.

6.4.9 Flammability Test

This procedure has been described per paragraph 6.3.2.7. As can be seen from Table CXIX, all of the paper base epoxy specimens from manufacturers A, B and C were self-extinguishing. This agrees with the manufacturers' test of being self-extinguishing.

The summary of all the physical property test results on paper epoxy are reported in Table CXX.

TABLE CII

DIELECTRIC CONSTANT TEST RESULTS OF MANUFACTURERS A, B, AND D

Paper Base Epoxy Laminate

Specimen Number	Material Thickness (Inch)	Copper Clad	Copper Foil Weight (Ounces)	Manufacturer	Dielectric Constant (One Megacycle)
1	3/32	Single	1 oz.	A	4.2
2	3/32	Single	1 oz.	A	4.2
3	3/32	Single	1 oz.	A	4.2
4	3/32	Single	1 oz.	A	4.2
5	3/32	Single	1 oz.	A	4.2
				Average Value	4.2
6	1/8	Single	1 oz.	A	4.3
7	1/8	Single	1 oz.	A	4.2
8	1/8	Single	1 oz.	A	4.3
9	1/8	Single	1 oz.	A	4.2
10	1/8	Single	1 oz.	A	4.2
				Average Value	4.2
11	3/32	Single	1 oz.	B	4.3
12	3/32	Single	1 oz.	B	4.3
13	3/32	Single	1 oz.	B	4.3
14	3/32	Single	1 oz.	B	4.3
15	3/32	Single	1 oz.	B	4.3
				Average Value	4.3
16	1/8	Single	1 oz.	B	4.2
17	1/8	Single	1 oz.	B	4.2
18	1/8	Single	1 oz.	B	4.1
19	1/8	Single	1 oz.	B	4.2
20	1/8	Single	1 oz.	B	4.2
				Average Value	4.2
21	3/32	Single	1 oz.	D	4.9
22	3/32	Single	1 oz.	D	4.9
23	3/32	Single	1 oz.	D	5.0
24	3/32	Single	1 oz.	D	5.0
25	3/32	Single	1 oz.	D	4.9
				Average Value	4.9
26	1/8	Single	1 oz.	D	4.8
27	1/8	Single	1 oz.	D	4.7
28	1/8	Single	1 oz.	D	4.8
29	1/8	Single	1 oz.	D	4.8
30	1/8	Single	1 oz.	D	4.7
				Average Value	4.8

TABLE CIII

DISSIPATION FACTOR TEST RESULTS OF MANUFACTURERS A, B, AND D

Paper Base Epoxy Laminate

Specimen Number	Material Thickness (Inch)	Copper Clad	Copper Foil Weight (Ounces)	Manufacturer	Dielectric Constant (One Megacycle)
1	3/32	Single	1 oz.	A	0.037
2	3/32	Single	1 oz.	A	0.037
3	3/32	Single	1 oz.	A	0.037
4	3/32	Single	1 oz.	A	0.038
5	3/32	Single	1 oz.	A	0.038
				Average Value	0.038
6	1/8	Single	1 oz.	A	0.040
7	1/8	Single	1 oz.	A	0.039
8	1/8	Single	1 oz.	A	0.038
9	1/8	Single	1 oz.	A	0.038
10	1/8	Single	1 oz.	A	0.038
				Average Value	0.039
11	3/32	Single	1 oz.	B	0.040
12	3/32	Single	1 oz.	B	0.039
13	3/32	Single	1 oz.	B	0.039
14	3/32	Single	1 oz.	B	0.039
15	3/32	Single	1 oz.	B	0.039
				Average Value	0.039
16	1/8	Single	1 oz.	B	0.038
17	1/8	Single	1 oz.	B	0.039
18	1/8	Single	1 oz.	B	0.039
19	1/8	Single	1 oz.	B	0.039
20	1/8	Single	1 oz.	B	0.039
				Average Value	0.038
21	3/32	Single	1 oz.	D	0.047
22	3/32	Single	1 oz.	D	0.048
23	3/32	Single	1 oz.	D	0.048
24	3/32	Single	1 oz.	D	0.047
25	3/32	Single	1 oz.	D	0.047
				Average Value	0.048
26	1/8	Single	1 oz.	D	0.047
27	1/8	Single	1 oz.	D	0.047
28	1/8	Single	1 oz.	D	0.048
29	1/8	Single	1 oz.	D	0.048
30	1/8	Single	1 oz.	D	0.048
				Average Value	0.047

TABLE CIV

FLEXURE TEST RESULTS OF MANUFACTURER A (1/32 INCH THICKNESS)

Paper Base Epoxy Laminate

Specimen Number	Copper Foil	Copper Clad	Composite Material Thickness	Breaking Load (Pounds)	Maximum Deflection (Inch)	Maximum Fiber Stress-S (P.S.I.)
Lengthwise Values						
1	One Side	1 oz.	1/32	32	.070	30.720
2	One Side	1 oz.	1/32	32	.075	30.720
3	One Side	1 oz.	1/32	32	.075	30.720
4	One Side	1 oz.	1/32	32	.070	30.720
5	One Side	1 oz.	1/32	33	.070	31.680
6	One Side	1 oz.	1/32	33	.070	31 680
7	One Side	1 oz.	1/32	33	.070	31.680
8	One Side	1 oz.	1/32	33	.080	31.680
					Average Value	31,200
Crosswise Values						
9	One Side	1 oz.	1/32	26	.070	24,960
10	One Side	1 oz.	1/32	32	.070	30,720
11	One Side	1 oz.	1/32	28	.070	26,680
12	One Side	1 oz.	1/32	27	.075	25,920
13	One Side	1 oz.	1/32	28	.075	26,880
14	One Side	1 oz.	1/32	27	.070	25,920
15	One Side	1 oz.	1/32	33	.080	31,680
16	One Side	1 oz.	1/32	27	.075	25,920
					Average Value	27,360

TABLE CV

FLEXURE TEST RESULTS OF MANUFACTURER A (1/16 INCH THICKNESS)

Paper Base Epoxy Laminate

Lengthwise Values						
1	One Side	1 oz.	1/16	58	-	22,272
2	One Side	1 oz.	1/16	58	-	22,272
3	One Side	1 oz.	1/16	56.5	-	21,696
4	One Side	1 oz.	1/16	56	-	21,504
5	One Side	1 oz.	1/16	56	-	21,504
6	One Side	1 oz.	1/16	56.5	-	21,696
7	One Side	1 oz.	1/16	55	-	21,120
8	One Side	1 oz.	1/16	55	-	21,120
					Average Value	21,640
Crosswise Values						
9	One Side	1 oz.	1/16	45	-	17,280
10	One Side	1 oz.	1/16	45.5	-	17,472
11	One Side	1 oz.	1/16	48	-	18,432
12	One Side	1 oz.	1/16	49.5	-	19,008
13	One Side	1 oz.	1/16	49	-	18,816
14	One Side	1 oz.	1/16	47	.140	18,048
15	One Side	1 oz.	1/16	45	.140	17,280
16	One Side	1 oz.	1/16	48	.140	18,432
					Average Value	18,090

TABLE CVI

FLEXURE TEST RESULTS OF MANUFACTURER A (3/32 INCH THICKNESS)

Paper Base Epoxy Laminate

Specimen Number	Copper Foil	Copper Clad	Composite Material Thickness	Breaking Load (Pounds)	Maximum Deflection (Inch)	Maximum Fiber Stress-S (P.S.I.)
Lengthwise Values						
1	One Side	1 oz.	3/32	92	.180	23,500
2	One Side	1 oz.	3/32	94	.180	25,100
3	One Side	1 oz.	3/32	95	.180	25,300
4	One Side	1 oz.	3/32	96	.185	25,600
5	One Side	1 oz.	3/32	94	.180	25,100
6	One Side	1 oz.	3/32	90	.180	24,000
7	One Side	1 oz.	3/32	93	.180	24,800
8	One Side	1 oz.	3/32	93	.180	24,800
					Average Value	24,700
Crosswise Values						
9	One Side	1 oz.	3/32	73	.180	19,450
10	One Side	1 oz.	3/32	75	.180	19,990
11	One Side	1 oz.	3/32	81	.185	21,550
12	One Side	1 oz.	3/32	76	.170	20,200
13	One Side	1 oz.	3/32	82	.180	21,800
14	One Side	1 oz.	3/32	76	.170	20,200
15	One Side	1 oz.	3/32	80	.180	21,300
16	One Side	1 oz.	3/32	76	.180	20,200
					Average Value	20,586

TABLE CVII

FLEXURE TEST RESULTS OF MANUFACTURER A (1/8 INCH THICKNESS)

Paper Base Epoxy Laminate

Specimen Number	Copper Foil	Copper Clad	Composite Material Thickness	Breaking Load (Pounds)	Maximum Deflection (Inch)	Maximum Fiber Stress-S (P.S.I.)
Lengthwise Values						
1	One Side	1 oz.	1/8	122	.260	23,424
2	One Side	1 oz.	1/8	119	.245	22,848
3	One Side	1 oz.	1/8	120	.240	23,040
4	One Side	1 oz.	1/8	119	.250	22,848
5	One Side	1 oz.	1/8	119	.250	22,848
6	One Side	1 oz.	1/8	114	.250	21,888
7	One Side	1 oz.	1/8	119	.260	22,848
8	One Side	1 oz.	1/8	118	.250	22,656
					Average Value	22,800
Crosswise Values						
9	One Side	1 oz.	1/8	107	.300	20,544
10	One Side	1 oz.	1/8	105	.260	20,160
11	One Side	1 oz.	1/8	107	.230	20,544
12	One Side	1 oz.	1/8	108	.250	20,736
13	One Side	1 oz.	1/8	109	.250	20,928
14	One Side	1 oz.	1/8	107	.250	20,544
15	One Side	1 oz.	1/6	107	.260	20,544
16	One Side	1 oz.	1/8	103	.250	19,776
					Average Value	20,472

TABLE CVIII

FLEXURE TEST RESULTS OF MANUFACTURER A (1/4 INCH THICKNESS)

Paper Base Epoxy Laminate

Specimen Number	Copper Foil	Copper Clad	Composite Material Thickness	Breaking Load (Pounds)	Maximum Deflection (Inch)	Maximum Fiber Stress-S (P.S.I.)
Lengthwise Values						
1	One Side	1 oz.	1/4	112	.310	21,504
2	One Side	1 oz.	1/4	108	.340	20,736
3	One Side	1 oz.	1/4	115	.350	22,080
4	One Side	1 oz.	1/4	116	.370	22,272
5	One Side	1 oz.	1/4	107	.330	20,544
6	One Side	1 oz.	1/4	125	.400	24,000
7	One Side	1 oz.	1/4	108	.340	20,736
8	One Side	1 oz.	1/4	122	.385	23,424
					Average Value	21,912
Crosswise Values						
9	One Side	1 oz.	1/4	83	.300	15,936
10	One Side	1 oz.	1/4	98	.365	18,816
11	One Side	1 oz.	1/4	98	.370	18,816
12	One Side	1 oz.	1/4	87	.310	16,704
13	One Side	1 oz.	1/4	88	.325	16,896
14	One Side	1 oz.	1/4	98	.375	18,816
15	One Side	1 oz.	1/4	88	.360	16,896
16	One Side	1 oz.	1/4	90	.310	17,280
					Average Value	17,520

TABLE CIX

FLEXURE TEST RESULTS OF MANUFACTURER B (1/32 INCH THICKNESS)

Paper Base Epoxy Laminate

Specimen Number	Copper Foil	Copper Clad	Composite Material Thickness	Breaking Load (Pounds)	Maximum Deflection (Inch)	Maximum Fiber Stress-S (P.S.I.)
Lengthwise Values						
1	One Side	1 oz.	1/32	34	.070	32,640
2	One Side	1 oz.	1/32	34	.070	32,640
3	One Side	1 oz.	1/32	30	.065	28,800
4	One Side	1 oz.	1/32	27	.050	25,920
5	One Side	1 oz.	1/32	28	.065	27,880
6	One Side	1 oz.	1/32	29	.075	27,840
7	One Side	1 oz.	1/32	29	.070	27,840
8	One Side	1 oz.	1/32	29	.070	27,840
					Average Value	28,800
Crosswise Values						
9	One Side	1 oz.	1/32	23	.060	22,080
10	One Side	1 oz.	1/32	25	.060	24,000
11	One Side	1 oz.	1/32	25	.060	24,000
12	One Side	1 oz.	1/32	23	.050	22,080
13	One Side	1 oz.	1/32	23	.050	22,080
14	One Side	1 oz.	1/32	24	.060	23,040
15	One Side	1 oz.	1/32	26	.060	24,960
16	One Side	1 oz.	1/32	28	.060	26,880
					Average Value	23,640

TABLE CX

FLEXURE TEST RESULTS OF MANUFACTURER B (1/16 INCH THICKNESS)

Paper Base Epoxy Laminate

Specimen Number	Copper Foil	Copper Clad	Composite Material Thickness	Breaking Load (Pounds)	Maximum Deflection (Inch)	Maximum Fiber Stress-S (P.S.I.)
Lengthwise Values						
1	One Side	1 oz.	1/16	55	.150	21,120
2	One Side	1 oz.	1/16	51	.150	19,584
3	One Side	1 oz.	1/16	53	.150	20,352
4	One Side	1 oz.	1/16	51	.145	19,584
5	One Side	1 oz.	1/16	49	.140	18,816
6	One Side	1 oz.	1/16	54	.140	20,736
7	One Side	1 oz.	1/16	52	.140	19,968
8	One Side	1 oz.	1/16	52	.145	19,968
					Average Value	20,016
Crosswise Values						
9	One Side	1 oz.	1/16	42	.130	16,128
10	One Side	1 oz.	1/16	48	.140	18,432
11	One Side	1 oz.	1/16	45	.140	17,280
12	One Side	1 oz.	1/16	44.5	.130	17,088
13	One Side	1 oz.	1/16	47.5	.135	18,240
14	One Side	1 oz.	1/16	45	.130	17,280
15	One Side	1 oz.	1/16	45	.130	17,280
16	One Side	1 oz.	1/16	45	.130	17,280
					Average Value	17,376

TABLE CXI

FLEXURE TEST RESULTS OF MANUFACTURER B (3/32 INCH THICKNESS)

Paper Base Epoxy Laminate

Lengthwise Values						
1	One Side	1 oz.	3/32	85	.200	22,600
2	One Side	1 oz.	3/32	83	.200	22,100
3	One Side	1 oz.	3/32	83	.195	22,100
4	One Side	1 oz.	3/32	87	.200	23,200
5	One Side	1 oz.	3/32	86	.200	22,900
6	One Side	1 oz.	3/32	85	.198	22,600
7	One Side	1 oz.	3/32	83	.190	22,100
8	One Side	1 oz.	3/32	87	.200	23,200
					Average Value	22,600
Crosswise Values						
9	One Side	1 oz.	3/32	67	.180	17,850
10	One Side	1 oz.	3/32	71	.180	18,900
11	One Side	1 oz.	3/32	70	.170	18,690
12	One Side	1 oz.	3/32	69	.170	18,400
13	One Side	1 oz.	3/32	69	.170	18,400
14	One Side	1 oz.	3/32	66	.160	17,600
15	One Side	1 oz.	3/32	65	.150	17,300
16	One Side	1 oz.	3/32	66	.160	17,600
					Average Value	18,092

TABLE CXII

FLEXURE TEST RESULTS OF MANUFACTURER B (1/8 INCH THICKNESS)

Paper Base Epoxy Laminate

Specimen Number	Copper Foil	Copper Clad	Composite Material Thickness	Breaking Load (Pounds)	Maximum Deflection (Inch)	Maximum Fiber Stress-S (P.S.I.)
Lengthwise Values						
1	One Side	1 oz.	1/8	109	.240	20,928
2	One Side	1 oz.	1/8	109	.240	20,928
3	One Side	1 oz.	1/8	107	.240	20,544
4	One Side	1 oz.	1/8	115	.260	22,080
5	One Side	1 oz.	1/8	110	.230	21,120
6	One Side	1 oz.	1/8	107	.230	20,544
7	One Side	1 oz.	1/8	116	.280	22,272
8	One Side	1 oz.	1/8	112	.240	21,504
					Average Value	21,240
Crosswise Values						
9	One Side	1 oz.	1/8	92	.250	17,664
10	One Side	1 oz.	1/8	90	.240	17,280
11	One Side	1 oz.	1/8	84	.240	16,128
12	One Side	1 oz.	1/8	92	.240	17,664
13	One Side	1 oz.	1/8	91	.240	17,472
14	One Side	1 oz.	1/8	92	.220	17,664
15	One Side	1 oz.	1/8	90	.220	17,280
16	One Side	1 oz.	1/8	90	.220	17,280
					Average Value	17,2[illegible]0

TABLE CXIII

FLEXURE TEST RESULTS OF MANUFACTURER B (1/4 INCH THICKNESS)

Paper Base Epoxy Laminate

Specimen Number	Copper Foil	Copper Clad	Composite Material Thickness	Breaking Load (Pounds)	Maximum Deflection (Inch)	Maximum Fiber Stress-S (P.S.I.)
Lengthwise Values						
1	One Side	1 oz.	1/4	114	.370	21,888
2	One Side	1 oz.	1/4	108	.370	20,736
3	One Side	1 oz.	1/4	119	.400	22,848
4	One Side	1 oz.	1/4	115	.380	22,080
5	One Side	1 oz.	1/4	105	.345	20,160
6	One Side	1 oz.	1/4	112	.380	21,504
7	One Side	1 oz.	1/4	111	.370	21,312
8	One Side	1 oz.	1/4	110	.365	21,120
					Average Value	21,456
Crosswise Values						
9	One Side	1 oz.	1/4	89	.345	17,088
10	One Side	1 oz.	1/4	94	.365	18,048
11	One Side	1 oz.	1/4	84	.310	16,128
12	One Side	1 oz.	1/4	89	.350	17,088
13	One Side	1 oz.	1/4	89	.340	17,088
14	One Side	1 oz.	1/4	94	.350	18,048
15	One Side	1 oz.	1/4	92	.350	17,664
16	One Side	1 oz.	1/4	94	.350	18,048
					Average Value	17,400

TABLE CXIV

FLEXURE TEST RESULTS OF MANUFACTURE D (1/32 INCH THICKNESS)

Paper Base Epoxy Laminate

Specimen Number	Copper Foil	Copper Clad	Composite Material Thickness	Breaking Load (Pounds)	Maximum Deflection (Inch)	Maximum Fiber Stress-S (P.S.I.)
Lengthwise Values						
1	One Side	1 oz.	1/32	19	.070	28,500
2	One Side	1 oz.	1/32	19	.070	28,500
3	One Side	1 oz.	1/32	18	.060	27,000
4	One Side	1 oz.	1/32	19	.060	28,500
5	One Side	1 oz.	1/32	18	.050	27,000
6	One Side	1 oz.	1/32	19	.060	28,500
7	One Side	1 oz.	1/32	18	.065	27,000
8	One Side	1 oz.	1/32	19	.070	28,500
					Average Value	27,937
Crosswise Values						
9	One Side	1 oz.	1/32	15	.070	22,500
10	One Side	1 oz.	1/32	15	.065	22,500
11	One Side	1 oz.	1/32	19	.065	28,500
12	One Side	1 oz.	1/32	17	.060	25,500
13	One Side	1 oz.	1/32	18	.060	27,000
14	One Side	1 oz.	1/32	17	.060	25,500
15	One Side	1 oz.	1/32	17	.065	25,500
16	One Side	1 oz.	1/32	15	.060	22,500
					Average Value	24,937

TABLE CXV

FLEXURE TEST RESULTS OF MANUFACTURER D (1/16 INCH THICKNESS)

Paper Base Epoxy Laminate

Lengthwise Values						
1	One Side	1 oz.	1/16	52	.130	19,968
2	One Side	1 oz.	1/16	52	.140	19,968
3	One Side	1 oz.	1/16	51	.130	19,584
4	One Side	1 oz.	1/16	52	.135	19,968
5	One Side	1 oz.	1/16	52	.145	19,968
6	One Side	1 oz.	1/16	51	.140	19,584
7	One Side	1 oz.	1/16	51.5	.140	19,776
8	One Side	1 oz.	1/16	52	.145	19,968
					Average Value	19,848
Crosswise Values						
9	One Side	1 oz.	1/16	44	.135	16,896
10	One Side	1 oz.	1/16	42.5	.130	16,320
11	One Side	1 oz.	1/16	44.5	.138	17,088
12	One Side	1 oz.	1/16	42	.130	16,128
13	One Side	1 oz.	1/16	44	.140	16,896
14	One Side	1 oz.	1/16	44	.130	16,896
15	One Side	1 oz.	1/16	43	.135	16,512
16	One Side	1 oz.	1/16	43	.138	16,512
					Average Value	16,656

TABLE CXVI

FLEXURE TEST RESULTS OF MANUFACTURER D (3/32 INCH THICKNESS)

Paper Base Epoxy Laminate

Specimen Number	Copper Foil	Copper Clad	Composite Material Thickness	Breaking Load (Pounds)	Maximum Deflection (Inch)	Maximum Fiber Stress-S (P.S.I.)
Lengthwise Values						
1	One Side	1 oz.	3/32	72	.180	22,500
2	One Side	1 oz.	3/32	75	.180	23,450
3	One Side	1 oz.	3/32	74	.185	23,100
4	One Side	1 oz.	3/32	72	.180	22,500
5	One Side	1 oz.	3/32	74	.180	23,100
6	One Side	1 oz.	3/32	74	.170	23,100
7	One Side	1 oz.	3/32	74	.170	23,100
8	One Side	1 oz.	3/32	73	.170	22,800
					Average Value	22,956
Crosswise Values						
9	One Side	1 oz.	3/32	63	.170	19,700
10	One Side	1 oz.	3/32	61	.160	19,050
11	One Side	1 oz.	3/32	63	.165	19,700
12	One Side	1 oz.	3/32	63	.170	19,700
13	One Side	1 oz.	3/32	62	.160	19,375
14	One Side	1 oz.	3/32	64	.170	20,000
15	One Side	1 oz.	3/32	62	.165	19,375
16	One Side	1 oz.	3/32	62	.160	19,375
					Average Value	19,530

TABLE CXVII

FLEXURE TEST RESULTS OF MANUFACTURER D (1/8 INCH THICKNESS)

Paper Base Epoxy Laminate

Lengthwise Values						
1	One Side	1 oz.	1/8	101	.240	19,392
2	One Side	1 oz.	1/8	96	.220	18,432
3	One Side	1 oz.	1/8	94	.220	18,048
4	One Side	1 oz.	1/8	101	.230	19,392
5	One Side	1 oz.	1/8	101	.230	19,392
6	One Side	1 oz.	1/8	98	.220	18,816
7	One Side	1 oz.	1/8	100	.280	19,200
8	One Side	1 oz.	1/8	99	.240	19,008
					Average Value	18,960
Crosswise Values						
9	One Side	1 oz.	1/8	78	.180	14,976
10	One Side	1 oz.	1/8	76	.220	14,592
11	One Side	1 oz.	1/8	77	.230	14,784
12	One Side	1 oz.	1/8	78	.190	14,976
13	One Side	1 oz.	1/8	74	.200	14,208
14	One Side	1 oz.	1/8	81	.210	15,552
15	One Side	1 oz.	1/8	78	.200	14,976
16	One Side	1 oz.	1/8	83	.220	15,936
					Average Value	15,001

TABLE CXVIII

FLEXURE TEST RESULTS OF MANUFACTURER D (1/4 INCH THICKNESS)

Paper Base Epoxy Laminate

Specimen Number	Copper Foil	Copper Clad	Composite Material Thickness	Breaking Load (Pounds)	Maximum Deflection (Inch)	Maximum Fiber Stress-S (P.S.I.)
Lengthwise Values						
1	One Side	1 oz.	1/4	115	.360	22,080
2	One Side	1 oz.	1/4	119	.360	22,848
3	One Side	1 oz.	1/4	111	.340	21,312
4	One Side	1 oz.	1/4	114	.360	21,888
5	One Side	1 oz.	1/4	120	.380	23,040
6	One Side	1 oz.	1/4	107	.340	20,544
7	One Side	1 oz.	1/4	122	.380	23,424
8	One Side	1 oz.	1/4	105	.310	20,160
					Average Value	21,912
Crosswise Values						
9	One Side	1 oz.	1/4	92	.340	17,664
10	One Side	1 oz.	1/4	99	.360	19,008
11	One Side	1 oz.	1/4	91	.340	17,472
12	One Side	1 oz.	1/4	82	.295	15,744
13	One Side	1 oz.	1/4	98	.365	18,816
14	One Side	1 oz.	1/4	99	.360	19,008
15	One Side	1 oz.	1/4	99	.375	19,008
16	One Side	1 oz.	1/4	94	.345	18,048
					Average Value	18,096

TABLE CXIX

FLAMMABILITY TEST RESULTS OF MANUFACTURERS A, B, AND C

Paper Base Epoxy Laminate

Manufacture (Copper Clad Both Sides)	Composite Material Thickness (Inches)	Copper Foil Weight (Ounces)	Self Extinguishing or Burn Rate Time
A	1/16	1 oz.	16 Specimens Run - All Self-Ext.
A	3/32	2 oz.	16 Specimens Run - All Self-Ext.
B	1/16	1 oz.	16 Specimens Run - All Self-Ext.
B	3/32	2 oz.	16 Specimens Run - All Self-Ext.
C	1/16	1 oz.	16 Specimens Run - All Self-Ext.
C	3/32	2 oz.	16 Specimens Run - All Self-Ext.

TABLE CXX

SUMMARY OF THE PHYSICAL PROPERTY TEST RESULTS OF PAPER BASE EPOXY LAMINATE

TABLE III. Property values

Property to be tested (see table IX)	Conditioning procedure (see 4.5.1.4 to 4.5.1.4.3, incl)	Type PX				
		1/32 inch thick	1/16 inch thick	3/32 inch thick	1/8 inch thick	1/4 inch thick
Copper-foil resistivity, at 20° C, average, maximum, ohms (gram/meter square).	A	0.17210				
Solder dip:						
Unetched specimens................	A	NO BLISTERING NOR DELAMINATION				
Etched specimens..................	A	NO INTERLAMINAR BLISTERING				
Peel strength, minimum, pounds per inch width:[1,2]						
1-oz copper:						
After solder dip..................	A	10.1	9.9	9.5	8.3	10.4
After temperature cycling........	(3)	10.2	10.0	9.7	10.3	10.9
After elevated temperature.......	E-1/140	10.1	10.4	10.1	9.6	10.1
2-oz copper:						
After solder dip..................	A	13.0	14.7	14.3	12.5	12.9
After temperature cycling........	(3)	14.7	14.3	14.2	12.0	12.8
After elevated temperature.......	E-1/140	14.7	14.5	14.1	13.3	13.4
Volume resistivity, minimum, megohm-centimeters.	C-96/35/90	...	3.15×10^8	5.16×10^8	3.28×10^8	...
Surface resistance, minimum, megohms	C-96/35/90	...	18.4×10^5	18.6×10^5	23.4×10^5	...
Water absorption, average, maximum, percent.	E-1/105+des +D-24/23	...	0.457	0.290	0.320	...
Dielectric breakdown (parallel to laminations), average, minimum, kilovolts:						
Step-by-step test................	D-48/50+D $-\frac{1}{2}$/23	47.7	50.3	55.0	54.7	54.4
Dielectric constant, average maximum, at 1 megacycle.	D-48/50+D $-\frac{1}{2}$/23	...	...	4.47	4.40	...
	D-24/23	...	...	...	...	...
Dissipation factor, average, maximum, at 1 megacycle.	D-48/50+D $-\frac{1}{2}$/23	...	...	0.042	0.041	...
	D-24/23	...	...	...	...	...
Flexural strength, average, minimum, psi:[1]						
Lengthwise	A	29,300	20,500	23,400	21,000	21,750
Crosswise	A	25,300	17,350	19,350	17,550	17,600
Flexural strength at elevated temperature, average, minimum, percentage of condition-A value obtained on test:						
Lengthwise	E-1/150	...	...	...	...	...
Arc resistance, average, minimum, seconds.	D-48/50+D $-\frac{1}{2}$/23	...	...	...	...	.
Flammability, average, maximum, burning time in seconds.	A	...	...	...	..	...

[1] For any one thickness, one-half the number of specimens shall be cut crosswise and one-half cut lengthwise.

[2] No blistering nor delamination shall be evident upon removal from the solder pot or the oven, or at the end of cycling.

[3] Conditioning shall consist of five cycles before test. For paper-base type, procedure shall be: $E-\frac{1}{2}/100+\frac{1}{4}/25+\frac{1}{2}/-55+\frac{1}{4}/25$

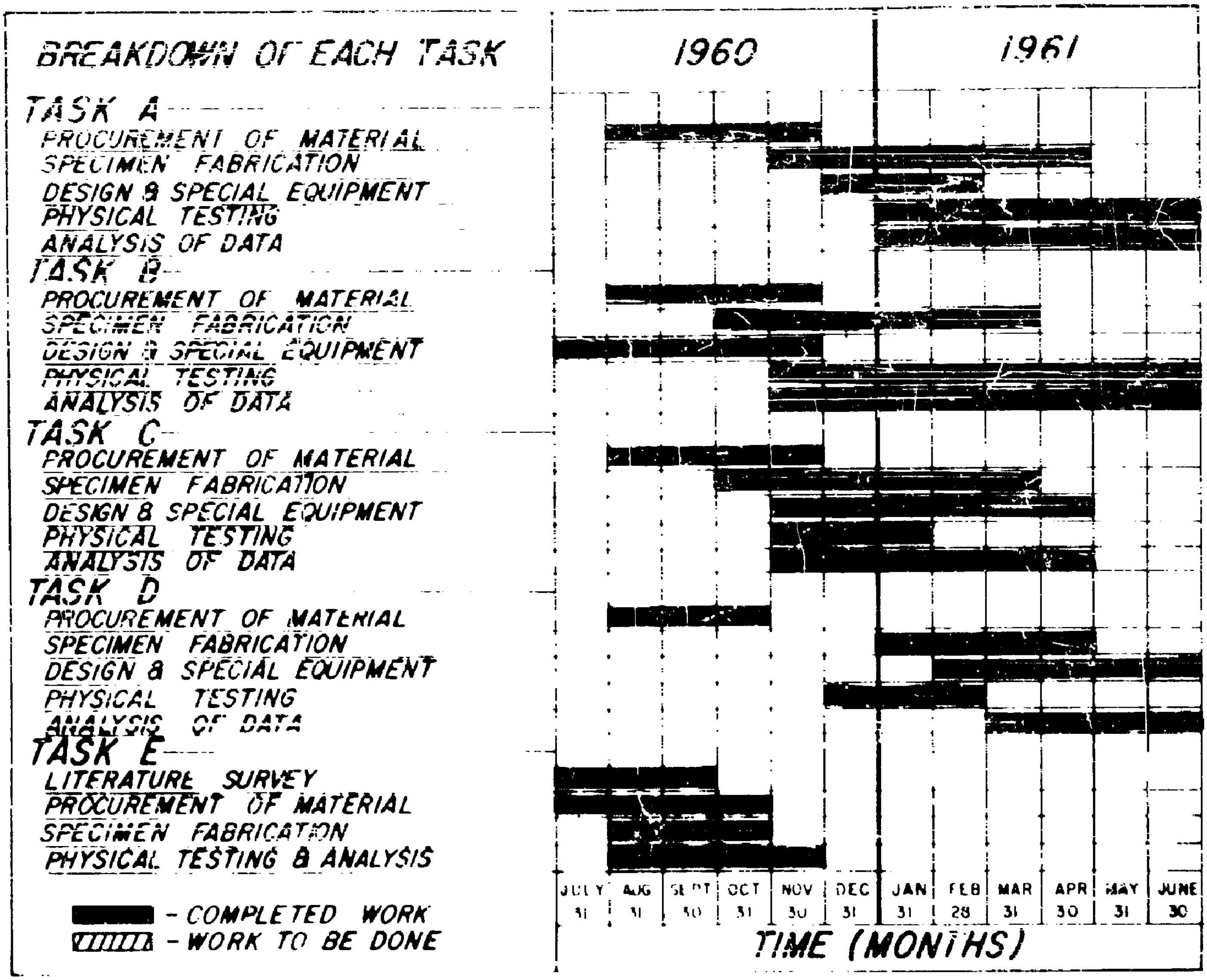


Figure No. 87. Project Performance and Schedule Chart

APPENDIX A - A NON-DESTRUCTIVE TEST TO EVALUATE THE EFFECT OF NICKS, PIN HOLES AND SCRATCHES ON PRINTED WIRING CONDUCTORS.

Scope - This test establishes criteria and a technique for evaluating the effect of nicks, pin holes and scratches on printed wiring conductors so that allowable cross-section reduction may be established on any given printed wiring board. This test may be used either to evaluate a specific line reduction condiction with a given current, or to establish dimensional criteria so the maximum allowable reduction of a specific system may be established with subsequent inspection by physical measurement to ensure compliance with standards established by this test.

Equipment Needed for Testing - The following equipment was used to establish the test procedure. Equivalent items may be substituted as necessary.

1. A Weston Model 931 D.C. Ampere Meter (scale division of 1/2 ampere)
2. 20 amp. Shunt
3. 8 ohm, 50 watt Rheostat
4. Two (125 V, 26 amp.) Knife Switches
5. One 6 volt Battery (130 ampere hours)
6. Fenwal Temperature Meter (Model 58301-5)
7. Thermistor Bead (Fenwal No. GB34P92)
8. TW #8 Solid Copper Wire
9. Universal Timer (Model 167)
10. Jagabi Pile Rheostat (Model #10 - .018 to 1.8 ohms resistance)
11. Thermistor Bead Holding Device (see Figure No. 7)
12. Two Electrode Terminal Posts (see Figure No. 9 in Task A of the report)
13. One 6 volt Battery Booster
14. Test Board Chamber - this chamber may be constructed as in Figures No. 4 and 6 in Task A of the report)

The basic and pictorial electrical circuit hook-up is constructed as illustrated in the following pages: 9 + 10

Positioning of Test Board - Place the circuit board in an enclosed test area that will prevent any air currents from affecting temperature rise measurements. When the circuit board has been positioned in the test enclosure, a bead thermistor is positioned directly over the copper conductor and held firmly so that the bead makes firm physical contact with that portion of the copper conductor that is to be tested.

The two electrodes (see Figure No. 6 in Task A of the report) are placed on opposite sides of the thermistor beads (make sure that the distance between electrodes does not exceed 1.50 inches).

Electrical Test Procedure - Before current is allowed to flow in the conductor, the temperature meter is turned on to measure the ambient temperature in the conductor test area. This is recorded after an elapsed time of 3 or 4 minutes. The knife switches in the circuit are closed, allowing current to flow through the copper conductor. Temperature rise readings are taken at 1 amp intervals. The current flow is controlled by the carbon pile rheostat. For amperage values exceeding 5 amps, the 8 ohm rheostat is removed from the circuit, (see Figure No. 6 in Task A of the report), stabilize before taking the temperature reading. Temperature rise measurements are taken for each ampere increment up to a temperature rise of 40°C above ambient. The temperature should be allowed to stablilize for approximately five minutes after each change in current before reading.

Acceptance Conditions for Passing or Failing the Tested Circuit Board - The principal factor which will determine whether or not the degree of line reduction is acceptable is the amount of current required to raise the conductor temperature to 40°C above ambient. If this current value is in excess of that which will flow in the conductor during normal use (with an allowance for surge currents), than the degree of line reduction can be considered acceptable and my be used to establish physical limits which may be measured on subsequent boards in the same system.

It must be noted, however, that if any of the following conditions develop during testing, then the part should be considered as failing, regardless of the amount of current which passed through:

1. Discoloration of copper at point of maximum reduction.

2. Discoloration of base laminate around test area.

3. Lifting or wrinkling of the conductor from the base laminate.

It should be pointed out that the evaluation of the effect of nicks, pin holes and scratches on printed wiring conductors is effected by many variables. A review of the data collected in Task A makes it appear that there is considerably more leway than had been previously considered. There are, however, other qualifying factors which must be taken into consideration. In the first place, conductor line width reduction in excess of 30 to 25% are outside the bounds of good manufacturing practice and should not normally be acceptable.

Another factor, and one which was unfortunately outside the scope of this study, is the possibility of long-term degradation, or gradual deterioration on the bond between the reduced conductor and the base material over extended periods of time at temperatures somewhat less than 40°C above ambient.

To assure reliability and minimize the possible effects of long time application of elevated temperatures which could cause ultimate degradation of the bond to failure, the following specifications limitations are recommeded.

1. For any given 1 inch length of conductor, individual nicks or pin holes or combination of nicks and pin holes which expose the base laminate, or any scratch shall not reduce the cross-section area of the conductor by more than 30%.

2. For any given 1 inch length of conductor no combination of nicks or pin holes which expose the base laminate, or any scratch shall be acceptable when the cross-section area at the point of maximum reduction shows a temperature increase in excess of 40°C when examined in accordance with the procedure outlined in Appendix ~~B~~ A.

APPENDIX B - GENERAL PROCEDURE FOR PREPARING TEST SPECIMENS

Visual Inspection - The sheet material of copper-clad plastic laminate, in as-received condition, was inspected for superficial defects such as scratches, pits, blisters, dents and other defects which might be observed by visual inspection. If any of the above defects occurred exceeding requirements per MIL-P-13949B, the sheet material was rejected and sent back to the manufacturer for replacement.

Machining - The required number of specimens were cut by a saw from the entire sheet for each test. The specimens for Task A were cut to a size 4.50" x 2.75" x thickness of material.

Cleaning - Those specimens that required a specific pattern, after having been machined, were thoroughly scrubbed, using a grade FFF pumice and a wad of moistened cotton. This was done to minimize scratches when scrubbing lengthwise and crosswise. The specimens were then rinsed with warm water (approximately 90°F) until the specimen would hold an unbroken film of water. The specimen was then dried with filtered air. After drying, the specimens were carefully handled from the edges and placed in a suitable clear rack for the next process operation. Lint-free gloves were used at all times for handling.

Sensitizing - All specimens requiring a specific pattern were sprayed with a Kodak Photo Resist solution, using a Binks No. 20 production spray gun. The time of spraying was approximately two seconds. The specimens were then removed and put aside to dry. It was necessary that the sensitized surfaces be undisturbed while drying in an infra-red oven at 150°F for a minimum of one-half hour.

Printing - After the sensitizing solution had thoroughly dried, the specimen, along with a negative of the pattern required, was placed in a vacuum frame with the coated side up and the required negative emulsion down to ensure emulsion to emulsion contact. The specimen was exposed to an ultra-violet light for 2-1 2 minutes under a vacuum pressure of 28 inches.

Developing - The specimen was then removed from the vacuum frame and placed in the developer (trichloroethylene) for two minutes. After this it was removed and allowed to cool before dipping for approximately one second. It was then removed from the dye and immediately washed in a spray of warm water (80° to 100°F) until only the required pattern remained on the copper foil (approximately one minute). Following this, the excess water was removed with a warm blast of air and the specimen was set aside to dry for approximately one hour.

Etching - The specimens after being thoroughly dried were placed in an oscillating head spray etching machine (42° Baume Ferric Chloride) for three to six minutes until all of the excess copper was removed. The temperature of the etching solution was maintained at around 75 to 100°F.

Cleaning and Drying - The specimens were then removed from the etching tank and immediately washed in cold running water for 15 minutes minimum. They were then washed in a 10 percent oxalic acid solution followed by a 5 minute rinse in cold running water, after which they were thoroughly rinsed with distilled water. The excess water was removed with clean absorbent cotton and a warm air blast. All specimens were then placed in an oven at 80°C ± 3°C for one hour minimum and then allowed to cool. The specimens were bagged from this point on to prevent contamination.

APPENDIX C - INSULATION RESISTANCE TEST

Scope - The purpose of this test is to set the requirements that will give reproducible and consistent insulation test results.

Equipment Required - The following types of equipment were used to establish the data for this test. Equivalent substitutes may be made as necessary.

1. A Humidity Test Chamber that will control the humidity and temperature within the limits as specified in MIL-STD-202. (See Figures 35, 36 and 37 in Task B of the report).

2. Test specimen holders and electrode connectors similar to those shown in Figures 38 and 40 in Task B of the report.

3. Teflon insulated coasial cable (Type RG-142V).

4. Keithley Model 610A Electrometer (used to measure current).

5. A 500 volt DC Power Supply. (Keithley power supply model 2004A or equal).

6. A Hewlett-Packard Model 412A Vacuum Tube Voltmeter.

7. Appropriate test leads for wiring of electrical circuit.

- Note: An accurate megohmmeter capable of measuring resistance up to 10^{14} ohms with an accuracy of ± 6%, and also capable of providing a sustained voltage of 500V D.C. may be substituted for items 4, 5 and 6.

Specimen Preparation - For most accurate results, testing should be started as soon after specimen manufacture as possible.

The specimens are fabricated as stated in Appendix B to simplify production. The following cleaning operation is recommended:

1. Scrub with pumice or Ajax and Tampico brush.

2. Rinse 1 - 2 minutes in spray water rinse.

3. Rinse 4 - 6 minutes in running water rinse.

4. Immerse in versene solution (1 oz. per gallon) for 2-4 minutes.

5. Rinse 2 - 4 minutes in hot (min. 155°F) deionized water.

6. Blow dry with clean filtered air, or blot dry with kimwipe and bag immediately. (All handling during cleaning should be with white cotton or synthetic fiber gloves.)

7. Put the specimens in an air circulating oven for 1 hour at 80° ± 3C before putting the specimens in the humidity test chamber.

Test Procedure - Turn the Keithley Electrometer, Power Supply and the VTVM or Megohmmeter on sufficiently ahead of test to allow a warm-up period of 30 minutes. Ground the specimens at all times. Refer to Figure No. 42 for the basic electrical hook-up circuit. To initiate testing the specimen is energized with 500 volts for one minute before the current is read. Measuring the insulation resistance by the indirect method enables an accuracy of ± 6% at 10^{14} ohms range to be

reached (current measured with a Keithley Electrometer Model 610A). At the end of each current reading the specimen just tested is grounded before the next specimen is measured. The 500 volt line voltage is monitored continuously with a Hewlett-Packard Model 412A Voltmeter. Referring to Figure No. 42, change leads 1 and 2 for measuring volume resistance. The insulation measurements are performed by guarding the back electrode and applying the potential across the outer and center ring of the bullseye pattern. Those insulation resistance test patterns that are not of a bullseye pattern design, the insulation readings are performed by applying the potential across opposite leads of the respective test pattern. In this case it is a two-electrode system and not a three-electrode system when measuring insulation resistance with this type of pattern design.

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